

KANSAS DEPARTMENT OF HEALTH AND ENVIRONMENT

POLICIES, GENERAL CONSIDERATIONS AND

DESIGN REQUIREMENTS

FOR

PUBLIC WATER SUPPLY SYSTEMS IN KANSAS



STATE OF KANSAS
DEPARTMENT OF HEALTH AND ENVIRONMENT
DIVISION OF ENVIRONMENT
BUREAU OF WATER
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ABBREVIATIONS

ABBREVIATION

DEFINITION

ANSI	American National Standards Institute
APHA	American Public Health Association
API	American Petroleum Institute
ASAP	As Soon As Possible
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AWWA	American Water Works Association
BAT	Best Available Technology
CAFO	Concentrated Animal Feeding Operations
CCPP	Calcium Carbonate Precipitation Potential
CFD	Computational Fluid Dynamics
CFR	Code of Federal Regulations
CPVC	Chlorinated Polyvinyl Chloride
CT	Concentration-Time Product
DAF	Dissolved Air Flotation
DBPs	Disinfection By-Products
DIP	Ductile Iron Pipe
DIPRA	Ductile Iron Pipe Research Association
DWR	Division of Water Resources
DO	Dissolved Oxygen
DOT	Department of Transportation
ED	Electrodialysis
EDR	Electrodialysis Reversal
EPCRA	Emergency Planning and Community Right-to-Know Act
FRP	Fiberglass Reinforced Plastic
G	Velocity Gradient
GAC	Granular Activated Carbon
GFCI	Ground Fault Circuit Interrupter
GIS	Geographical Information System
GWR	Groundwater Rule
GWUI	Groundwater Under the Direct Influence of Surface Water
HAA5	Haloacetic Acids (5)
HCW	Horizontal Collector Well
HDPE	High Density Polyethylene
HPC	Heterotrophic Plate Count
IOCs	Inorganic Chemicals
ISO	Insurance Services Office (formerly; now simply ISO)
KAR	Kansas Administrative Regulation

ABBREVIATIONS (Continued)

ABBREVIATION

DEFINITION

KDHE	Kansas Department of Health and Environment
KDWP	Kansas Department of Wildlife and Parks
KGS	Kansas Geological Survey
KSA	Kansas Statutes Annotated
KWO	Kansas Water Office
LOX	Liquid Oxygen
LP	Low Pressure
LPHO	Low Pressure High Output
LT2ESWTR	Long-Term 2 Enhanced Surface Water Treatment Rule
MCL	Maximum Contaminant Level
MF	Microfiltration
MP	Medium Pressure
MRDL	Maximum Residual Disinfectant Level
NEMA	National Electric Manufacturers Association
NF	Nanofiltration
NIOSH	National Institute of Occupational Safety and Health
NPDES	National Pollutant Discharge Elimination System
NPSH	Net Positive Suction Head
NSF	National Sanitation Foundation
NTU	Nephelometric Turbidity Unit
O&M	Operation and Maintenance
OSHA	Occupational Safety and Health Administration
PAC	Powdered Activated Carbon
PAHs	Polycyclic Aromatic Hydrocarbons
pK _w	Ion Product of Water
PSA	Pressure Swing Adsorption
PTFE	Polytetrafluoroethylene
PVC	Polyvinyl Chloride
PVDC	Polyvinylidene Chloride
PVDF	Polyvinylidene Fluoride
PWS	Public Water Supply
PWSSs	Public Water Supply Systems
RCRA	Resource Conservation and Recovery Act
RED	Reduction Equivalent Dose
RMP	Risk Management Plan
RO	Reverse Osmosis
SCADA	Supervisory Control and Data Acquisition
SDWA	Safe Drinking Water Act
SI	Saturation Index
SMCL	Secondary Maximum Contaminant Level

ABBREVIATIONS (Continued)

ABBREVIATION

DEFINITION

SOCs	Synthetic Organic Chemicals
SWA	Source Water Assessment
SWAP	Source Water Assessment Program
SWTR	Surface Water Treatment Rule
TFM	Technical, Financial and Managerial
TOC	Total Organic Carbon
TSA	Thermal Swing Adsorption
TTHMs	Total Trihalomethanes
UF	Ultrafiltration
UL	Underwriters Laboratories
UV	Ultraviolet
UPS	Uninterruptible Power Source
USEPA	United States Environmental Protection Agency (EPA)
UVDGM	UV Disinfection Guidance Manual
UVT	UV Transmittance, %
VOCs	Volatile Organic Chemicals
VSA	Vacuum Swing Adsorption
WEF	Water Environment Federation

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UNITS OF MEASUREMENT

<u>Measurement</u>	<u>U.S. System</u>	<u>International System</u>
Linear	inch (in)	millimeter (mm)
	foot (ft)	centimeter (cm)
	mile (mi)	meter (m)
		kilometer (km)
Area	square inch (in ²)	square meter (m ²)
	square foot (ft ²)	hectare (ha)
	square mile (mi ²)	
	acre (ac)	
Time	second (sec)	second (s)
	minute (min)	minute (min)
	hour (h or hr)	hour (h or hr)
	day (d)	day (d)
Velocity	feet/second (ft/sec)	meters/second (m/s)
Volume	gallon (gal)	liter (L)
	million gallons (MG)	cubic meter (m ³)
	acre-feet (ac-ft)	
Flow	gallons/minute (gpm)	liters/minute (L/min)
	million gallons/day (MGD)	cubic meters/second (m ³ /s)
	standard ft ³ /minute (scfm)	standard m ³ /minute (m ³ /min)

UNITS OF MEASUREMENT (Continued)

<u>Measurement</u>	<u>U.S. System</u>	<u>International System</u>
Weight	ounce (oz)	gram (g)
	pound (lb)	
Density	pound-mass/cubic foot (lb/ft ³)	grams/liter (g/L)
Pressure (Head)	pounds-force/square inch (psi)	kilopascal (kPa)
		atmosphere (atm)
Energy	BTU	Joules
	horse power-hour (hp-hr)	kilowatt-hour (kWh)
Power	horsepower (hp)	Watts (W)
Temperature	centigrade (°C)	Celsius (C)
	Fahrenheit (°F)	
Slope	inches/foot (ipf)	meters/meter (m/m)
Concentration	pounds/gallon (lbs/gal)	moles/liter (mol/L)
	pounds/cubic foot (lbs/ft ³)	
	parts per million (ppm)	parts per million (ppm)
	parts per billion (ppb)	parts per billion (ppb)

The above summary of U. S. customary units and units specified for the International System is based on a report by the AWWA Metrication Committee (AWWA, 1982).

INTERNATIONAL SYSTEM MULTIPLICATION FACTORS, PREFIXES AND SYMBOLS

Multiplication Factors

<u>Decimal</u>	<u>Exponential</u>	<u>Prefix</u>	<u>Symbol</u>
1000000000	10^9	giga	G
1000000	10^6	mega	M
1000	10^3	kilo	k
0.001	10^{-3}	milli	m
0.000001	10^{-6}	micro	μ
0.000000001	10^{-9}	nano	n

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CHAPTER I

INTRODUCTION

A. HISTORY AND PRESENT SITUATION

The history of bulletins dealing with policies governing the design of PWSSs in Kansas was reviewed in 1984 (Metzler, 1984). The previous version of this bulletin was published by KDHE in 1995. Earlier versions were published in 1953, 1957, 1967 and 1984.

Under the authority of the 1986 Amendments to the Safe Drinking Water Act, the USEPA promulgated regulations that placed a new set of constraints on both KDHE and design engineers. KDHE decided to revise the 1984 bulletin to address these new constraints, to incorporate design considerations relevant to new technologies, and to update obsolescent portions of its design criteria. To that end, KDHE published a revised bulletin entitled "Policies, General Considerations and Design Requirements for Public Water Supply Systems in Kansas" in 1995.

Since 1995, additional regulations have been promulgated by USEPA, based in part on the 1996 Amendments to the Safe Drinking Water Act. KDHE decided to revise the 1995 bulletin to address these recent regulatory changes, to address recent technological developments, and to update obsolescent design criteria.

B. STATUTORY AUTHORITY AND CHARGE

KSA 65-171h authorizes and empowers the Secretary of KDHE "to develop, assemble, compile, approve and publish minimum standards of design, construction, and maintenance of sanitary water and sewage systems" and further states that the Secretary shall "publish and make available such approved minimum standards to municipalities, communities and citizens of this state." KSA 65-162a(b) defines a public water supply system as "a system for the provision to the public of piped water for human consumption, if such system has at least ten (10) service connections or regularly serves an average of at least twenty-five (25) individuals daily at least sixty (60) days out of the year. Such term includes any source, treatment, storage, or distribution facilities."

Public water systems can be publicly or privately owned and are subdivided for regulatory purposes into two major categories: community water supply systems and non-community water supply systems. KAR 28-15a-2 defines a non-community water supply system as one that is not a community water supply system or one that serves water to non-residential populations. Non-community water supply systems are further divided into non-transient non-community water supply systems (that serve the same non-residential populations over time such as those at schools and factories) and transient non-community water supply

systems (that serve different non-residential populations from day to day such as those visiting highway rest stops, restaurants, and motels). KAR 28-15a-2 defines a non-transient non-community water supply system as one that is not a community water supply system and that regularly serves at least 25 of the same persons over six months per year.

C. PURPOSE AND INTENT

The purpose of this bulletin is to document KDHE's policies and design requirements for PWSSs in Kansas and to also describe general considerations, guidelines and criteria applicable to the design of PWSSs in Kansas by water supply professionals. It is KDHE's intent that the bulletin will allow designers maximum freedom consistent with modern water supply practices. The standards of design are derived from state statutes and regulations that reflect KDHE's responsibilities to users of water produced by Kansas PWSSs.

The design criteria stated herein consist mainly of principles and requirements that have been in use over a long period of time in water supplies found in the State of Kansas. Their purpose is to provide guidelines and standards to those engaged in the design of new facilities and the upgrading of existing public water supply systems. Many of the principles and requirements outlined in certain sections of this bulletin were drawn, in some cases verbatim, from *Recommended Standards for Water Works: Policies for the Review and Approval of Plans and Specifications for Public Water Supplies, A Report of the Water Supply Committee of the Great Lakes – Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers*, commonly referred to as the "Recommended Standards" (Recommended Standards, 2003) or from earlier versions of these standards. Also, there are references to specific standards developed by the American Water Works Association, and all such references are to the most current version.

It is intended that designers using the criteria in this bulletin retain a maximum degree of design freedom since it is recognized that each water supply system is a unique entity and that certain changes to these criteria may be necessary to meet local conditions and unusual circumstances. Terms such as "should" or "recommended" indicate desirable guidelines with deviations subject to site-specific considerations. On the other hand, the terms "shall" and "must" are used where practice is standardized to permit specific delineation of requirements or where safeguarding of the public health justifies definite action. Even the terms "shall" and "must" are not absolutes in that KDHE may grant exceptions to these requirements under certain circumstances and with adequate justification provided by a licensed professional engineer. Also, it is not always possible to include design criteria for recently developed processes, methods, chemicals, and equipment although these developments may be acceptable to KDHE.

D. ORGANIZATION AND USE

This bulletin covers administrative procedures and general design considerations along with a review of specific design guidelines and standards. Any changes made subsequent to this edition of the bulletin will be posted to KDHE's web address: <http://www.kdheks.gov/pws/>.

Chapters I and II include an introduction to the design bulletin, Kansas statutes, regulations, procedures, required reports, and plans and specifications for PWSS projects. This portion of the bulletin is intended to assist project managers and engineers with having an awareness and an understanding of the administrative aspects of a PWSS project. Chapters IV through VIII include the recommended and required design criteria for each aspect of a PWSS: source development, treatment, storage, pumping, and distribution. General facility design considerations (Chapter III) are included in the bulletin as a prelude to the design chapters. And lastly, Chapter IX addresses chemical storage, handling, and application requirements. Selected subjects are addressed in the appendices to this bulletin.

The administrative procedures and design criteria contained herein will be most effective when implemented by a licensed professional engineer experienced in water works design. Further, subject to certain limited exceptions, KSA 74-7001 et seq. requires the use of licensed professional engineers for services or work constituting the practice of engineering. Therefore, KDHE strongly recommends that a water supplier contract with a licensed professional engineer to assist in preparing plans and specifications for any anticipated project. Any attempt to avoid using the services of a licensed professional engineer may compromise the technical requirements of the PWSS design and may result in less than adequate facilities.

E. LAWS AND REGULATIONS

Links to on-line versions of selected Kansas statutes and regulations pertaining to PWSSs are provided in Appendix A. Regulations are identified under their specific governing statute. Copies of current Kansas statutes and regulations pertaining to PWSSs may also be obtained from KDHE.

F. OTHER RESOURCES

This bulletin references certain resources available from other state agencies. It should be recognized that most of these agencies have compiled lists of publications which can be obtained and used to identify additional sources of information about cities, policies, reviews, strategies, surveys, water resources, etc. For example, Kansas Geological Survey has published numerous water-related reports and provides other resources such as maps, data bases, and computer programs. In addition, AWWA makes available a catalogue of publications covering numerous aspects of the design of water treatment and distribution systems. Also, two major references are available on water treatment plant design (AWWA and ASCE, 2005; and AWWA, 1999a).

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Chapter II

REPORTS, PLANS AND SPECIFICATIONS

A. PROCEDURES FOR WATER SUPPLY PROJECT APPROVAL

The following KDHE review procedure is designed to facilitate the efficient processing of PWSS projects as required by KSA 65-163 and KAR 28-15-16. Table II-1 summarizes the basic steps leading to KDHE approval, especially as they relate to the design engineer. The tasks are common to all water supply projects with a few exceptions. These deviations are identified and discussed following the general procedure for water supply project approval.

1. APPROVAL STEPS

- a. **PRELIMINARY REPORT PREPARATION (TASK 1)** – The preparation of a preliminary report by the engineer for the client outlines the alternatives that exist for public water supply improvements, extensions and where applicable consideration of regionalization. The client uses the report to make an assessment of possible actions and as a basis for directing the engineer to continue the investigation. The items covered in the report are similar to those required for the engineer's report.
- b. **ENGINEER'S REPORT PREPARATION AND SUBMISSION (TASK 2)** – The engineer's report consists of the details necessary to establish the proposed project design. KDHE approval of the engineer's report is not required but a copy must be submitted so that preparations can be made for the design concepts conference.
- c. **DESIGN CONFERENCE (TASK 3)** – A meeting is held with KDHE to establish the design concepts to be incorporated in the final design of the PWSS. KDHE is concerned primarily about the functional and sanitary features of the design; hence, the meeting is used to insure that the design engineer understands these requirements for the proposed design. KDHE will notify the engineer in writing about the acceptability of the proposed design.
- d. **PLANS, SPECIFICATIONS AND PERMIT APPLICATION SUBMISSION (TASK 4)** – The preparation of plans and specifications by the engineer must be based on the previously approved design approach. Also, KDHE has the authority to require a design revision if new information has been developed since the design concepts meeting. Deviations from the engineer's report must be identified and substantiated.

TABLE II-1

OUTLINE OF PUBLIC WATER SUPPLY PROJECT (GENERAL) PROCEDURE

Task No.	Action Required by Engineer	Timing for Engineer	Action Required by KDHE	Timing for KDHE
1	Preparation of preliminary report	None	None	None
2	Preparation and submission of engineer's report	Within 1 year after completion of Task No. 1	Comments optional	None
3	Schedule design concepts conference involving engineer and KDHE	None	Approval in writing	ASAP
4	Submission of plans, specifications, and permit application(s) Existing systems use existing system permit application New systems submit Parts 1 & 2 of a new system permit application (Part 2 is a TFM Capacity Development assessment)	Within 1 year after completion of Task No. 3 With plans Prior to construction	Approval in writing of plans and specifications, permit application(s) and, for new systems, a TFM Capacity Development assessment	ASAP after submission & prior to approval for construction
5	Initiation of construction steps	Within 2 years after completion of Task No. 4	None	None
6	Notification of completion and the construction cost by the engineer	ASAP after completion of construction	Post-construction inspection Issuance of permit	ASAP ASAP

The plans and specifications must be submitted to KDHE along with a notarized Public Water Supply Permit Application signed by the mayor, rural water district board chairman, city manager, or an official of the PWSS authorized to do business for the PWSS. The information in the permit application may be taken from the engineer's report or the plans and specifications.

Existing systems complete and submit for review the standard permit application; however, new systems must complete and submit for review a new system permit application Part 1 and Part 2. Part 1 is similar to the standard permit application for existing systems. Part 2 is an assessment entitled "Technical, Financial and Managerial Capacity Assessment for New Public Water Supply Systems." The 1996 Amendments to the Safe Drinking Water Act require that a new system demonstrate adequate Technical, Financial and Managerial (TFM) capacity before providing water service to their customers. The review and approval of the permit application Part 2 is part of KDHE's capacity development program. For new systems, Part 2 is submitted to KDHE for review and approval in addition to plans, specifications and a completed permit application Part 1. Permit applications for both existing systems and new systems are available at KDHE's web address: <http://www.kdheks.gov/pws/>.

KDHE requests that two sets of plans and specifications be submitted for all projects with the exception that only one set of plans and specifications be submitted for projects not requiring a final inspection and permit such as water line extensions. In order to facilitate processing and reduce costs, KDHE additionally requests that plan size be limited to 11"x17". Full size plan title pages requiring an approval stamp and return can be included in the submittal.

KDHE approval of the plans and specifications and the permit application may require several weeks after receipt of the required submittals, depending on the complexity of the project.

The project engineer must be cognizant of the need to submit plans, specifications, permit applications or other documentation to agencies or organizations other than KDHE. For example, KSA 82a-621 requires that plans, specifications, proposed operating budget and other specified documentation relating to the design and operation of a new rural water district be filed with the chief engineer of DWR.

In addition, construction projects that will disturb one or more acres of land are required to secure, prior to the start of construction, authorization to discharge stormwater runoff under the construction stormwater general permit S-MCST-0110-1. Information regarding this authorization can be

found at <http://www.kdheks.gov/stormwater/index.html#general> (on the Stormwater Program web site).

- e. INITIATION OF CONSTRUCTION (TASK 5) – After KDHE approves the plans and specifications and the permit application, bids can be solicited and the construction contract let. Delays in the initiation of construction over 2 years after approval will require re-submittal of the plans, specifications and permit application.
- f. NOTIFICATION, INSPECTION, AND APPROVAL (TASK 6) – As soon as the functional and sanitary facilities of the water system or water system modification are constructed and operational, the engineer must notify KDHE by letter so that a post-construction inspection can be made. The bid amount (construction cost) for the project is to be included in the notification.

If the construction is found to be in accordance with the approved plans and specifications, KDHE will issue a permit to the PWSS. The new facility or the modifications to an existing facility may then be placed into service.

- 2. SCOPE OF REVIEW – Task 3 in obtaining approval of a public water supply project identifies KDHE’s primary design concerns as the functional and sanitary features. This means that the engineer’s report and plans/specifications will be reviewed in these areas. “Functional” refers to the ability of a design to provide the required water quantity and accomplish the desired water quality changes. “Sanitary” concerns reflect the public and operator health/safety aspects of the proposed design.
- 3. DEVIATIONS/MODIFICATIONS TO KDHE STANDARD APPROVAL PROCEDURE
 - a. WATER MAIN EXTENSIONS – Tasks 1 through 3 of Table II-1 will not be required for water main extensions unless specifically directed by KDHE or otherwise required by the funding source for the project. Water main extensions will not receive a post-construction inspection by KDHE; however, written notification of completion along with the project bid amount (construction cost) is still required. Further, a permit will not be issued for water main extensions less than 1 mile in total length and permit applications need not be completed and submitted for such projects. However, preparation and submission of plans and specifications is required for all water main extensions.
 - b. MINOR ADDITIONS/MODIFICATIONS TO PROCESSES – Tasks 1 through 3 of Table II-1 will not be required for minor additions or modifications to a treatment process unless specifically directed by KDHE or otherwise required by the funding source for the project. The engineer should contact the Chief of the Engineering and Permits Unit of the Public Water

Supply Section, KDHE, for specific clarification on whether an engineering report is necessary. It is anticipated that in lieu of Task 3, a teleconference will be sufficient for most projects if KDHE has questions or comments concerning a project.

- c. NEW WELLS – Tasks 1 through 3 of Table II-1 will not be required for new well construction unless specifically directed by KDHE or otherwise required by the funding source for this project. However, additional information must be submitted which is described in Subsection B.3 of this chapter including documentation of the absence of pollution sources and the availability of water quality sampling results. Such documentation and results shall be submitted along with the plans, specifications and permit application as discussed in Task 4. KDHE approval is required before new well construction can begin.

B. DOCUMENTATION REQUIREMENTS FOR WATER SUPPLY PROJECT APPROVAL

Tasks 1, 2, and part of 4 of the approval procedure consist of the preparation of a preliminary report, an engineer's report, and plans and specification. Tasks 1 and 2 serve different purposes but share similar coverage since a comprehensive view of the water supply situation is required. Task 4 uses the information derived in the report preparation steps to allow the completion of the project plans and specifications (and also the Public Water Supply Permit Application). The following listings summarize the information generally necessary to establish the proposed design (preliminary and engineer's reports) and the specific requirements (plans and specifications) for its construction. Detailed design information for these outlined items is presented in Chapter V.

1. PRELIMINARY AND ENGINEER'S REPORTS – The preliminary report (Task 1) is preliminary in that it is the client's first formal look at the project alternatives as proposed by the engineer. It differs from the engineer's report (Task 2) in its limited detail and the still tentative recommendations. The engineer's report represents the final assessment of the water supply project alternatives prior to seeking approval from KDHE.

This report includes a detailed review of the existing water situation along with the data and considerations used to establish the proposed design. Alternative proposals are compared so that the relative merits of each are apparent. Cost analyses are made to justify the proposed design and include estimates of the capital and O&M costs along with the recommended method of financing. Recommended coverage for the preliminary and engineer's reports includes the various topics reviewed in the design guidelines and standards section, especially the items discussed in Chapter V.

2. PLANS AND SPECIFICATIONS (GENERAL) – All pertinent construction information must be included in the plans and/or the specifications. The following

outline summarizes the recommended location for such information where applicable. Another accepted format is the Construction Specifications Institute format, a standardized format used to facilitate the preparation and review of plans and specifications.

a. PLANS AND GENERAL REQUIREMENTS

- 1) Suitable title
- 2) Name of legal entity or responsible person
- 3) Area of entity to be served
- 4) Scale
- 5) North arrow
- 6) Datum used
- 7) Name and address of design engineer
- 8) Imprint, date of placement of engineer's seal, and engineer's signature
- 9) Legible prints suitable for reproduction

b. PLANS AND PROJECT DESIGN REQUIREMENTS

- 1) Summary of facilities' proposed sizes and design criteria for major facilities.
- 2) Summary of sizes, known design criteria and yields for existing facilities.
- 3) Location and nature of existing facilities affecting or having a relationship to the proposed improvements.
- 4) Boundaries of area to be served.
- 5) Relative locations of existing and proposed:
 - a) Water main lengths (with sizes);
 - b) Sewers and drains (with sizes and with distances relative to water main locations shown in plan and profile views);

- c) Other sources of pollution;
 - d) Chemical storage areas, feed equipment and points of application; and
 - e) Sampling taps.
- 6) Locations, dimensions, and elevations of proposed facilities.
- 7) Schematic flow diagrams and hydraulic profiles through the plant.
- 8) Piping details for plant flow schemes.
- 9) 100-year flood elevation and known flood elevations relative to facilities.
- 10) Topography and arrangement of facilities.
- 11) Stream crossings with bed elevations and water profiles for low, normal, and flood flows.
- 12) Plan and profile drawings for well construction.
- 13) Description of features or facilities not covered by specifications.
- c. SPECIFICATIONS – Complete and detailed specifications shall be supplied for the proposed project including:
 - 1) Same labeling as labeling of plans;
 - 2) Imprint, date of placement of engineer's seal, and engineer's signature;
 - 3) A program for keeping existing water works facilities both in operation and in compliance with the drinking water regulations during construction;
 - 4) Laboratory facilities and equipment;
 - 5) The design of chemical storage, handling, and application facilities (Chapter IX);
 - 6) Materials or proprietary equipment for sanitary or other facilities including any necessary backflow or back siphonage protection; and

- 7) Additional information relevant to construction, but not included in the plans.

3. DOCUMENTATION REQUIREMENTS FOR NEW WELLS

The following documentation, in addition to a public water supply permit application, should be provided for all new wells:

- a. **LOCATION DETAILS** – A plan, sketch or topographic map with scale, north arrow and title showing the location of the proposed water supply well with respect to roads, houses, wells, and potential sources of pollution such as sewer lines, privies, cesspools, septic tanks, lateral fields, animal feedlots, and underground storage tanks or pipes for petroleum products or chemicals. In addition, the test wells used in locating and designing the proposed water supply well should be clearly indicated on the drawing.
- b. **WELL DETAILS** – A plan or sketch showing the type of well construction to be used. Items to be shown include: depth and diameter of the drill hole; type of material, diameter, weight and thickness of the casing, the well screen, and the gravel pack; the thickness and depth of the grout; the extension of the well casing above the existing ground level; the 100-year flood elevation or the highest known flood level at the well location; the well vent; the drawdown gauge; the discharge line including the meter, the check and gate valves; the pump motor and concrete pedestal for a vertical turbine installation; the sanitary well seal in the case of above ground discharge for a submersible turbine pump, or the pitless unit in the case of below ground discharge for a submersible pump; the chlorination equipment and point of chlorine application; the raw well water and chlorinated water sampling taps; and the well house. In addition, the lithologic log(s) and formation sampling results from the test well(s) which were relied on in locating and designing the proposed water supply well should be submitted to KDHE along with any hydrologic data from preliminary pump tests.
- c. **WATER LINE DETAILS** – Provide a sketch showing the connection of the water line from the proposed well to the distribution system. In addition, provide details of the pipe diameter, material of construction, depth of burial, details of trenching and backfilling, specifications for the separation of the water line from pollution sources, pressure and leak testing, and disinfection procedures to be used in the construction of the water line.
- d. **DOCUMENTATION OF ABSENCE OF POLLUTION SOURCES** – Document by easement or letter that no potential sources of pollution will be allowed within 100 feet (30.5 m) of the well as described in Chapter IV.

- e. WATER SAMPLING – Provide analytical results from analysis of water samples collected from the aquifer in which the well is to be completed as described in Subsection B.4 of this chapter and in Appendix B.

4. WATER SAMPLING REQUIREMENTS FOR NEW SOURCES (SURFACE WATERS AND WELLS)

KAR 28-15-16(d) requires new water supply sources to be sampled and analyzed for certain bacteriological, chemical and radiological constituents. Required analytical parameters for monitoring new sources are presented in Appendix B along with recommended sampling procedures. Analytical results must be submitted to KDHE in addition to the plans, specifications, and permit application before final approval will be granted. It is important to keep abreast of the requirements of both current and proposed drinking water regulations during the development of new sources as additional long term monitoring may be required and the results of that monitoring may necessitate changes in treatment. This section as well as Appendix B and its Attachments A and B will be updated as the Rules are promulgated.

5. DOCUMENTATION REQUIREMENTS FOR TREATMENT PLANT MODIFICATIONS

A public water supply permit application and submission of plans and specifications are required for alterations or improvements involving a change in the treatment methods or the design capacity. A change in disinfection practice is also a change in treatment. Accordingly disinfection profiles and benchmarks (USEPA, 1999a) and CT ratio and log inactivation calculations for both the existing and proposed disinfection practice must be submitted to KDHE for review. Changes in design capacity may be as simple as installing a larger capacity pump or as complex as the addition of new water supply system infrastructure. Both would require submission of the above to KDHE for review and approval.

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CHAPTER III

GENERAL FACILITIES CONSIDERATIONS

A. GENERAL DESIGN GUIDELINES AND STANDARDS

Design guidelines and standards are presented below for the general considerations associated with PWSS facilities. Design criteria for the various other, more specific aspects of a PWSS (i.e., source development, treatment, storage, pumping, distribution, and chemical storage, handling and application) are included in the remaining chapters.

1. ALTERNATIVE SOLUTIONS AND REGIONALIZATION – Feasible alternatives should be considered for a PWSS design, e.g., KSA 19-3545 to 19-3556 provide for cooperative water supplies via the Public Wholesale Water Supply District Act. This act allows water supply entities to take advantage of the benefits associated with regionalization of water systems. It requires significant prior planning before these benefits can be realized. Also, interconnections between systems are encouraged.
2. SERVICE NEEDS – An appraisal of future requirements for service must include all potential users including residential, commercial, institutional, and industrial. Historical water use and population data should be used to project minimum, average, and maximum daily needs. The KWO compiles water use data for many Kansas municipalities that can be used to estimate the needs for similar cities (KWO, 2006). The possibility of fire flows or other heavy demands should also be considered along with water losses. Water savings from implemented water conservation programs should be recognized. The water source(s) and treatment facilities shall be designed for the maximum day demand at the end of the design period.
3. DESIGN PERIODS – The planned installation of any PWSS component requires an estimate of its needed capacity and the expected life of its major materials of construction. A 20 to 30 year design period is typical of most installations (e.g., intake structures, pump stations, and treatment works), but a 50-year design period is not uncommon for major impoundments, intakes, and long raw water transmission lines. Shorter design periods of 10 to 20 years are appropriate for scattered wells and other less costly structures.

Phased construction of “as needed” facilities is permitted but supporting facilities not built economically and conveniently in stages should be constructed with capacities for future use. Examples of “as needed” facilities include pumps, tanks, and additional treatment trains.

4. CONSERVATION – The design should conserve water, chemicals and power. Every activity demanding significant energy should be evaluated and considered in comparing design alternatives. Emphasis should be placed on water conservation. This includes the recycling of water in the treatment sequence (consistent with the Filter Backwash Recycling Rule), reduction of leakage and unnecessary use in the distribution system, and the utilization of water saving devices and methods. KWO has published guidelines and reviewed measures for water conservation (KWO, 1990 and 2007). DWR and KWO require conservation programs for PWSSs requesting new appropriations or purchasing water from federal reservoirs. DWR may require existing PWSSs to initiate a conservation program if their water use is determined to be excessive.
5. NEW PROCESSES, METHODS, CHEMICALS, AND EQUIPMENT – Designs or designs containing processes, methods, chemicals and/or equipment viewed as being innovative or “non-standard” will be considered for approval if they can be demonstrated to be both effective and economical over the anticipated range of water quality, flow, time, weather, and climate. Also, operator skills and equipment support for the innovative design must be demonstrated. The design engineer must submit to KDHE a detailed plan of testing for the proposed innovation, and after its approval, must document the test conclusions showing why an exception should be granted to the minimum design standards. Furthermore, the following conditions will apply:
 - a. The PWSS must obtain from the equipment supplier or contractor performance guarantees for the innovative equipment, process, or design. Copies of the performance guarantees are to be provided to KDHE upon request.
 - b. The PWSS, by official document action, must certify that it is aware of the potential risks of the “non-standard” equipment, process, or design; that it has the funds to refinance and construct a conventional process to replace the failed system; and that it will ensure that adequate treatment will be provided until the failed system is replaced.
 - c. Conditional approvals of designs, processes or equipment considered to be innovative or “non-standard” are to be interpreted as one-time site specific approvals only; thus, such an approval does not guarantee subsequent approval at that same site or at any other site. Each proposed application will be considered on a case-by-case basis and shall be discussed with the Chief of the Public Water Supply Section of the Bureau of Water prior to approval.
6. WASTE HANDLING AND DISPOSAL – Important considerations in evaluating alternative treatment processes are the quantities and characteristics of waste streams generated by the treatment sequence. The quantities and characteristics of the individual waste streams depend on source water quality, the processes utilized and

the chemicals applied in those treatment processes. Some treatment processes may not be viable because of the cost of, or regulatory restrictions on, the handling and disposal of the waste streams generated.

In the design of water treatment facilities, provisions must be made for proper disposal of all water treatment plant waste streams in accordance with local, state and federal regulations. KDHE strongly recommends that the review of handling and disposal of waste streams with regard to the requirements of the National Pollutant Discharge Elimination System (NPDES) permitting program for the state of Kansas be initiated early on in the design process.

7. COSTS AND FINANCING – Cost estimates shall be made for all alternative designs and shall include their capital and O&M costs. Sources and methods of financing the recommended design shall be identified. USEPA has published a resource guide for financial assistance programs for small water supply systems (USEPA, 1989).
8. SECURITY – Water system facilities shall be designed to include measures to provide protection against vandalism, terrorist acts, access by non-authorized personnel or any other types of unauthorized activities. Such measures shall include locked security doors; windows with security locks, or sized or barred to prevent human entrance; surveillance systems; lighting; controlled points of access; and security fencing around drinking water systems (e.g., wellheads, manholes, pump houses, treatment buildings and storage facilities).

B. PLANT SITING CONSIDERATIONS

1. EVALUATION OF ALTERNATIVE SITES – In general, the selection of the plant site should include a comparison of the following features for each site alternative and for present and future needs:
 - a. Source water quality;
 - b. Availability and cost of land, including taxes;
 - c. Site preparation requirements for cleaning, grading, and landscaping;
 - d. Identification of easements and acquisition of right-of-ways;
 - e. Site drainage, flood protection, and impacts of construction on drainage and flooding;
 - f. Soil, foundation, and groundwater conditions;
 - g. Adaptability to plant layout needs;

- h. Adjacent and surrounding developments;
 - i. Public attitude toward proposed facilities;
 - j. Availability of needed utility services (with two independent power sources being preferred, to minimize standby needs, but with auxiliary on-site generation being an acceptable substitute for key equipment and facilities);
 - k. Convenience to roads, highways, and railroads;
 - l. Emergency, civil defense, and natural hazards;
 - m. Environmental restrictions and regulations;
 - n. Accommodation of future expansions; and
 - o. Securability of facilities.
2. PLANT SITING RESTRICTIONS – KAR 28-15-17 states that a new or expanded facility shall not be initiated or constructed at a site which the department determines:
- a. Is subject to a significant risk from earthquakes, floods, fires, or other disasters which could cause a breakdown of the PWSS or a portion of it;
 - b. Except for intake structures is within the floodplain of a 100 year flood, or is lower than the recorded high water level where appropriate records exist; or
 - c. Is adjacent to a major source of pollution that KDHE determines has a potentially adverse influence on the water supply.
3. PWSSs AND POLLUTION SOURCES – The capabilities of the existing and proposed water works must be evaluated considering possible effects of adjacent pollution sources. Such effects could include actual or potential impairment of raw or finished water quality.
4. SITE SURVEY – A site survey should be conducted for each new water treatment facility. A site survey is an organized effort that in part collects and assimilates pollution information for a given area. It includes an evaluation of watershed, stream, and storage characteristics in terms of their natural and developed states. Of paramount importance are temporal and spatial water quality variations. Existing and future pollution sources and pollution control facilities should be evaluated. A risk analysis should be done to evaluate pollution problems caused by transportation failure, ruptured oil tanks, or other potential sources of pollution.

5. SOURCE WATER ASSESSMENT – The 1996 Amendments to the Safe Drinking Water Act required each state to develop a SWAP to, in part, facilitate a SWA for each public water supply system that treats and/or distributes raw source water. A SWA includes the following: delineation of the source water assessment area; inventory of potential contaminant sources; and a susceptibility analysis. KDHE recommends that the system of interest be reviewed to determine if a SWA is required or if its SWA must be updated to reflect or support the proposed design changes. Information regarding SWAP and SWA can be found at KDHE's web address: <http://www.kdheks.gov/pws/>.

C. PLANT LAYOUT AND OTHER CONSIDERATIONS

1. PLANT AND BUILDING LAYOUT – Design of a PWSS site and facilities involves structural, functional, aesthetic, and cost considerations for the proposed and future additions. Applicable state and local building, electrical, fire, and plumbing codes more stringent than KDHE requirements must be met. Also, applicable ASTM, AWWA, and NSF International's ANSI/NSF standards must be satisfied. Design considerations include:
 - a. Centralized operation with accessibility to facilities;
 - b. Available utility service connections and adequate ventilation, lighting, heating, sewers, and drainage;
 - c. Elimination of operating inconveniences and hazardous conditions;
 - d. Enclosure, separation, and distribution of facilities;
 - e. Space for offices, meeting rooms, lunch room, laboratory, O&M areas, processes, and storage (with process areas also including room for equipment disassembly for maintenance);
 - f. Provision of access ways for water and waste streams, utilities, chemicals, drainage, flooding, O&M personnel, visitors, equipment, and vehicles;
 - g. Architecture, landscaping, buffer zones and neighbors;
 - h. Future expansion; and
 - i. Security provisions to prevent unauthorized access and protect from unauthorized activities that would otherwise adversely impact the system and/or disrupt the production of drinking of water.
2. MATERIALS OF CONSTRUCTION – The potential effects of weathering, corrosion, leaching of contaminants and scale formation should be evaluated for all

components of a PWSS. Materials, coatings, chemicals and lubricants that will contact or potentially contact source, partially treated or finished waters shall be appropriate for use in the production of drinking water in order to protect public health and the environment, and comply with NSF International's ANSI/NSF Standards 60 and 61, applicable AWWA standards, or equivalent. Also, the impact of corrosion products and control methods on water quality shall be considered. Contact between dissimilar metals should be avoided to minimize galvanic action.

A proposal that includes the use of mercury-containing lamps must include safeguards to minimize the possibility of on-line lamp breakage, a plan for the proper recycling (preferably) or disposal of used lamps, and a lamp break response plan (USEPA, 2006a). The response plan must include sampling and cleanup procedures, procedures for protecting the safety of both the consumers and the operators, and procedures for maintaining compliance with the SDWA, OSHA health and safety standards, the Clean Water Act, and RCRA.

3. VENTILATION AND DEHUMIDIFICATION – Designs shall consider the buildup of chemicals and/or moisture due to leakage and poor air circulation in confined spaces. These potential areas (such as pump stations, filter pipe galleries, chemical feed areas, and basements) should be properly cleaned, ventilated and/or dehumidified to prevent accidents and corrosion.
4. OPERATION AND MAINTENANCE – Considerations shall be given to the O&M requirements of proposed facilities in terms of anticipated manpower and equipment needs. Manpower needs include certified operators and maintenance personnel with the skills required to service the new system. Equipment needs should also include handling units for the removal of equipment. O&M manuals shall be provided and shall include parts lists and order forms for all equipment.
5. AUTOMATION – The servicing and operator training requirements for automatic equipment must be provided. Manual override is required for all automatic controls.
6. MONITORING, SAMPLING, AND LABORATORY REQUIREMENTS – Process instrumentation and analytical measurement devices shall be installed where necessary to satisfy operational and regulatory reporting requirements. Sampling taps shall be available to permit the collection of samples to satisfy KDHE's reporting and procedural requirements for various water quality analyses.

Analytical methods employed as part of satisfying monitoring and reporting requirements must be performed by KDHE laboratories or a KDHE certified laboratory. Analytical methods employed as part of controlling plant operations can be made without certification but every effort should be made to conform to the procedures described in the latest edition of *Standard Methods for the Examination of Water and Wastewater* (APHA et al., 2005) or those methods and procedures as otherwise required by the drinking water regulations.

7. EMERGENCY PLAN – Potential disasters must be anticipated and plans formulated to abate their effect upon the provision of a safe and adequate water supply. Disasters that must be considered include: tornado, drought, flood, storms, fire, explosion, sabotage, vandalism, civil disorder, nuclear attack and fall-out, and power, equipment and operator failures. KAR 28-15-18(c) requires each community water supply system to prepare an emergency operations plan to safeguard the water supply for the protection of the public if natural or man-made disasters occur. KDHE has prepared a guidance document to assist water utilities in the preparation and implementation of emergency plans (KDHE, 2005).
8. SAFETY – Accident prevention and emergency service equipment shall be provided to minimize operational hazards. This will include proper ventilation, approved electrical fixtures, handrails, guards, grating, warning signs, and protective clothing and equipment. Applicable OSHA and NIOSH standards must be satisfied.
9. CONTAMINATION OF SOURCE, PARTIALLY TREATED OR FINISHED WATERS – Under no circumstances shall a cross connection between a non-potable source and either a source water, a partially treated water or a completely treated water (e.g., finished water) be allowed. Facilities shall be designed to preclude contamination by plants, animals, insects or hazardous materials.
10. DISINFECTION – All wells, pipes, tanks, and equipment that can convey or store potable water shall be disinfected in accordance with current AWWA Standards. KAR 28-15-18(d) specifically requires that newly constructed or repaired water distribution mains and finished water storage facilities be flushed and disinfected before use. The plans and specifications shall outline the procedure and include the disinfection dosage, contact time, method of testing and the results of the procedure, and the appropriate de-chlorination and disposal of highly chlorinated disinfection solutions.
11. HYDRAULICS – A hydraulic profile of the PWSS must be determined for the proposed design. Also, consideration should be given to the required flow regimes for the system components.

Hydraulic profiles should be drawn for average, maximum and peak hydraulic conditions in order to set adequate freeboard in basins and channels, and thereby allow establishment of critical elevations for process units and support facilities. It is important to satisfy the hydraulic needs of the processes as well as acknowledge the topography of the site.

12. PIPING AND CHANNELS – All flow conveyance systems shall be designed to handle the maximum expected flow with due consideration to solids deposition problems. Operational flexibility should be provided by appropriate use of interconnections and bypasses to and around the system components. Extra wall castings should be provided for future pipe passages through concrete structures.

Chemical storage facilities should be kept close to unloading areas and points of chemical addition to reduce the length of chemical feed lines.

Table III-1 presents a recommended color scheme for identifying various PWSS pipes. It is required for new facilities. It is further recommended that the name of the liquid or gas be painted on the pipe with arrows indicating the direction of flow. When there is insufficient contrast between two colors, a 6 inch (15.2 cm) band of a color that does adequately contrast may then be painted on one pipe at intervals of approximately 30 inches (76 cm) in order to aid in distinguishing between the pipes.

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TABLE III-1
COLOR CODE FOR PWSS PIPING

Water Lines	Raw	Olive Green
	Settled	Aqua
	Finished or Potable	Dark Blue
Chemical Lines	Alum or Primary Coagulant	Orange
	Ammonia	White
	Carbon Dioxide	Dark Green with Red Band
	Carbon Slurry	Black
	Caustic	Yellow with Green Band
	Chlorine Gas	Yellow (under vacuum) Yellow with Red Band (under pressure)
	Chlorine Solution	Yellow with White Band
	Chlorine Dioxide	Yellow with Blue Band
	Fluoride	Light Blue with Red Band
	Lime Slurry	Light Green
	Ozone	Yellow with Orange Band
	Phosphate Compounds	Light Green with Red Band
	Polymers or Coagulant Aids	Orange with Green Band
	Potassium Permanganate	Violet
	Soda Ash	Light Green with White Band
	Sulfur Dioxide	Light Green with Yellow Band
	Sulfuric Acid	Red with Yellow Band
Waste Lines	Backwash Waste	Light Brown
	Process Waste	Dark Brown
	Sewer (Sanitary or other)	Dark Gray
Other	Compressed Air	Dark Green
	Gas	Red
	Other lines	Light Gray

Source: Adapted from *Recommended Standards for Water Works* (Recommended Standards, 2003).

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CHAPTER IV

SOURCE DEVELOPMENT

In selecting a source of water to be developed, the design engineer must determine that an adequate quantity of water exists for which a vested water right or permit to appropriate can be lawfully obtained and that the treated water delivered to the consumers will meet KDHE's PWS quality standards.

A. QUANTITY REQUIREMENTS

The quantity of water at the source shall be adequate to meet the projected maximum daily demand for the design period. Rights to the water must be obtained from DWR, which administers the Kansas Water Appropriation Act. A potential water user must make application to DWR to begin the process necessary to establish a water right (KWO, 2001). The time period for processing an application for a permit by DWR may be substantial. A processing time period of one year or more is not unusual. Assistance in completing an application can be obtained from any of the DWR field offices. The DWR considers a water use projection for twenty years reasonable for determining the requested quantity of water on an application to appropriate for municipal water supply use.

It is illegal for a PWSS in Kansas to use water without holding a vested right or applying for and receiving a permit to appropriate water. Also, it is important to recognize that some parts of Kansas have no water available for new permits. In those areas, acquisition of an existing water right and obtaining approval to change one or more of the water right's features may be the only way to meet future water needs. Features associated with an existing water right that must not be changed without DWR approval include the type of water use, the point of diversion (e.g., location of intake structure in a reservoir, stream, or river), or the place of water use. An acceptable meter must be installed on each diversion works in accordance with DWR's specifications, maintained in a satisfactory condition and used to provide the water usage information that is required to be in the annual water use report.

Yield restrictions for the various water resources are as follows:

1. FLOWING SOURCES – Where water is drawn from a flowing stream, river, or spring, DWR flow records should confirm its availability to meet the maximum daily demand for the design period during a 50-year drought with all prior water rights considered. The occurrence of a 100-year flood should not impair the proposed PWSS facilities.

2. IMPOUNDMENTS – Reservoirs and lakes used for PWS must meet the drought and flood restrictions of flowing streams. The effective storage needed to provide the firm yield shall take into account evaporation, seepage, and siltation losses. KWO handles requests for water from federal reservoirs through their water marketing program. As required by KSA 82a-301, DWR must approve all plans for construction of dams that impound more than 50 acre-ft (62,000 m³).
3. WELLS – Proposed well installations should be based on pumping test and/or historical records of withdrawal where available. Rights for withdrawal of groundwater must be obtained from DWR following a procedure similar to that for surface waters (KWO, 2001). DWR is assisted by Groundwater Management Districts in western and south central Kansas. Together they work to formulate and enforce local policies concerning the conservation, management, and control of water within each district.

B. QUALITY REQUIREMENTS

The quality of the proposed water resource should be determined for both average and extreme conditions of flow and climate. Major sources of historical water quality data are the Kansas Water Data Base and STORET maintained by KDHE and USEPA, respectively. In addition, KDHE requires that current water quality test results be submitted with permit applications for new sources (Appendix B). The quality of a particular water resource must be compared with PWS water quality and treatment requirements to determine the most cost effective treatment for a specific water resource. Current PWS water quality requirements are contained in KAR 28-15a, "Primary Drinking Water Regulations." Additional treatment requirements are specified in KAR 28-15-19, "Disinfection of drinking water." The designer must consider the worst conditions that may exist during the life of the facility.

C. SURFACE WATER – RESOURCE FACILITIES AND OTHER REQUIREMENTS

Surface water includes streams, rivers, impoundments, reservoirs, or other natural or man-made surface water sources. It can also include GWUI from a regulatory standpoint (Chapter V, Section M on Disinfection). In this discussion, springs are considered surface water sources while all types of wells are considered groundwater sources even though they may be regulated as GWUI.

1. FLOWING SOURCES

- a. STREAMS AND RIVERS – In selecting a location consider the effects of confluent streams, navigation requirements, water depth, trash, ice, 100-year flood level, water velocity, channel changes due to sand mining or silting, eutrophication, distances of separation from pollution sources, the possibility of shoal or bar formation, water quality and the effects of changing meteorological conditions on water quality, and access. Also evaluate quantity of supply, cost of development versus alternate locations and

sources, and possible need for an impounding reservoir, either in-channel or off-channel.

- b. SPRINGS – Springs will be approved only after an extensive sanitary survey has been completed. The requirements for the protection of the spring will be determined by KDHE. Minimal requirements for springs include:

- 1) Documentation must be provided to confirm the absence of pollution sources. Either ownership or a perpetual easement must be obtained by the owner of the spring for the land within 100 ft. (30.5 m) measured horizontally outward from the spring. In either case, positive assurance is to be provided that no septic tanks, wastewater facilities, sanitary sewers, force main, or tile absorption fields will be allowed within that area.

The owner may use the land for agricultural or pasture purposes except that livestock must be kept at least 100 ft. (30.5 m) away from the spring. Use of the land for any purpose shall not significantly contribute to pollution of the source water. Sanitary sewers to serve residential areas outside the 100 ft. (30.5 m) wide protected zone shall transport the wastewater, either treated or untreated, to either a point downstream from the spring or to a separate watershed.

If the land in question is owned by someone other than the owner of the PWSS, then a copy of a perpetual easement, detailing any limits or constraints on the use of the land by either party and showing the stamp of the Register of Deeds, must be submitted to KDHE. If the land is owned by the PWSS, then they must provide a letter to KDHE that acknowledges the ownership. Where the land in question is owned by the PWSS and other owners, the ownership letter and perpetual easements must be submitted to KDHE for the appropriate areas of land. In all cases, the documents must indicate that no potential sources of pollution will be allowed within 100 ft. (30.5 m) of the spring.

- 2) Springs located on a hillside or at the foot of a hill shall be avoided where sources of pollution are present on the slope above and within 300 ft. (91.4 m) horizontally of the spring. An adequate intercepting ditch shall be constructed and maintained so as to keep hillside storm water at least 100 ft. (30.5 m), measured horizontally, away from the spring.
- 3) Flood waters shall not approach closer than 100 ft. (30.5 m) to prevent contamination of the spring.

- 4) Proper drainage in the vicinity of the spring shall be provided so as to prevent the accumulation of surface water, either by runoff or backflow, to within 100 ft. (30.5 m) of the spring.
- 5) The intake structure and any pumping or water treatment facilities shall be enclosed in shelters which are weather and vandal resistant.
- 6) All water from springs shall be subjected to continuous disinfection and filtration as minimum treatment (Chapter V, Section M on Disinfection).
- 7) The spring area must be fenced to prevent unauthorized entry.

2. IMPOUNDMENTS

- a. **SITE SELECTION** – Consider topography, catchment area, potential pollution sources, nutrient sources, watershed management, storage capacity versus dam and spillway required, geology, safety, and water rights. The State Conservation Commission administers several programs dealing with watersheds and water resources which involve sources of funding for water supply development and improvement. A Kansas Water Resources Research Institute study reviewed the impact of watershed management practices on the use of multipurpose reservoirs and lakes (Randtke *et al.*, 1985).
- b. **RAW WATER CHARACTERISTICS** – Water quality variations for all conditions of stream flow should be considered.
- c. **PERMITS** – A permit for controlling stream flow, placing a structure on the bed of any stream, or approval of a dam or spillway design must be obtained from DWR. The requirements established by DWR are summarized in KSA 82a-301 through 305a, KAR 5-40-1 through 106 and KAR 5-42-5 (DWR, 2007).
- d. **LAKE USE** – The designation of a lake as single purpose or multi-purpose will be made by the owners of the lake. The State Conservation Commission administers the Multipurpose Small Lakes Program for small flood control, water supply, and/or recreational projects (State Conservation Commission, 2002). Recreational activities conducted in or on any water utilized as a source of water supply for a public water supply system must be conducted in such a manner that the water quality of the water will not be adversely affected by such activities. Swimming is not recommended in any water supply impoundment except at designated sites.

3. **SINGLE PURPOSE LAKES** – The following requirements must be met for single-purpose water supply lakes.

- a. Site preparation for the lake shall include removal of trees and brush to the conservation pool elevation without major disturbance of the original ground surface.
- b. Either ownership or a perpetual easement must be obtained by the owner of the lake for the land within 200 ft. (61 m) measured horizontally outward from the high water level elevation according to the same procedures cited for springs in this chapter. In either case, positive assurance is to be provided that no septic tanks, wastewater facilities, sanitary sewers, force mains, or tile absorption fields will be allowed within that area.

The owner may use the land for agricultural or pasture purposes except the livestock must be kept at least 15 ft. (4.6 m) away from the high water level elevation by fencing. Use of the land for any purpose shall not significantly contribute to pollution of the source water. Sanitary sewers to serve residential areas outside the 200 ft. (61 m) wide protected zone shall transport the wastewater, either treated or untreated, to either a point downstream from the lake or to a separate watershed. In all cases, the documents must indicate that no potential sources of pollution will be allowed within 200 ft. (61 m) of the lake.

- c. There shall be no upstream or direct discharges of untreated wastewater into the lake. Treated wastewater discharges must be approved by KDHE.
- d. A program to control algal growths and minimize taste and odor in the raw and/or treated water shall be carried out by the lake owner. KDHE has published a report relating taste and odor potentials in Kansas lakes to their trophic levels (Arruda and Fromm, 1988a).
- e. The owner shall carry out a program for maintenance of shorelines and control of aquatic weeds. It may be necessary at some time to lower the level of water in the lake to remove weeds and accumulated silt.
- f. Other than rock placed along bank lines for protection from erosion, no debris, trash, brush, fish habitat enhancement structures, or other solid materials may be placed in the lake for any purpose.
- g. During the planning process, the consulting engineer shall evaluate the watershed area for potential pollutant or nutrient contribution and project the effect that it may have on the eutrophication rate and water quality. Where the effect can be interpreted as contributing to taste and odor, drinking water quality standard violations, or DBP or turbidity problems, special attention to additional management of the lake watershed or to design of the treatment process will be required. KDHE and Kansas Water Resources Research Institute reports review the impact watershed pollutants have on

trihalomethane formation potential (Randtke *et al.*, 1987)(Arruda and Fromm, 1988b).

4. MULTIPURPOSE LAKES – For multipurpose lakes used primarily for public water supply purposes, the same requirements will apply as for single purpose lakes with the following exceptions:
 - a. Trees and brush may be left standing in the conservation pool area. These locations and the extent to which they may be covered by trees and brush shall be reviewed and approved by KDHE after consultation with KDWP on a case-by-case basis.
 - b. Artificial fish enhancement substrates may be utilized. The location, type and size of the area that may be covered by such substrates shall be reviewed and approved by KDHE.
 - c. Treatment of a lake surface to control algae is recommended rather than required.
5. INTAKE STRUCTURES – Intake designs for streams, rivers, lakes, and reservoirs or other natural or manmade surface water sources shall be approved by KDHE. Approval by the US Army Corps of Engineers or Bureau of Reclamation is also required for federal reservoirs. Listed below are requirements for intake structures.
 - a. Provide reliable and sufficient capacity to supply treatment plant flow requirements for a 20 to 40 year design period under minimum head conditions.
 - b. Locate intakes to avoid damage to aquatic life, excessive siltation or bank erosion, and runoff from sloughs and swamps. Protection against surges, ice, floods, floating debris, boats, and barges shall also be provided.
 - c. A floating log boom or other effective device should be used around the intake structure. Screens and grates should be used to protect pumps and treatment facilities and to minimize the intake of debris and aquatic life. Screens and grates should also be self-cleaning.
 - d. Inlet flow velocities of 0.25 to 0.5 ft/sec (0.08 to 0.15 m/s) will minimize frazil ice problems. Other control methods include injection of steam into pump suction, backflushing with settled water, use of air bubbler systems in front of gate openings, and locating the intake in still water.
 - e. Inlets or ports shall be located so that water may be admitted from a choice of depths to take advantage of favorable water quality. Their locations should be easily identified through permanent markers on the intake structures. A

choice of at least three depths should be provided. Withdrawal of water from more than one level is desirable in run-of-the-stream intakes if the water quality varies with depth.

The lowest inlet or gate port should be placed at the elevation where it will be entirely submerged at all water stages yet not too close to the stream bottom where a high sediment load may be encountered. Exposed or slightly submerged inlets should be avoided where potential navigational hazards exist. The lowest inlet location in a flowing source, lake or reservoir should consider future silt accumulations. Flowing source inlets may also be affected by channel changes caused by meandering, scouring or sand mining.

In general, the velocity through the gross area of the inlets or ports should not exceed 1.0 ft/sec (0.3 m/s). Removable racks with 0.5 to 0.75 inch (12.7 to 19.1 mm) diameter metal bars to provide 1 to 3 inch (25.4 to 76.2 mm) openings and velocities not to exceed 2 ft/sec (0.6 m/s) at maximum design flow through the openings should be used at the intake ports. Where ice accumulation may occur, a velocity of less than 0.5 ft/sec through the net area of the rack is recommended. Smaller debris can be removed using screens with 0.375 inch (9.5 mm) or smaller openings and velocities similar to those for racks.

- f. Inspection manholes should be located every 1000 ft. (305 m) for pipe sizes large enough to permit visual inspection and for occasional cleaning of the inlet line. Conduit velocities should be 3 to 4 ft/sec (0.9 to 1.2 m/s) to avoid deposition of solids. Straight lines on a rising or falling grade should be used to avoid the accumulation of air. If this is not possible, provisions to release accumulated air must be provided at the high points in the inlet line.
- g. Shore shafts or pump wet wells should provide storage for intake water at the design flow and minimum head conditions, adequate pump submergence, and surge capacity in the event of power failure. Fixed and traveling screens can be located in the shore shaft. Motors and electrical controls should be located above grade and protected from flooding. Shore shafts should be accessible, designed against flotation, provided with chemical addition points if necessary, and fitted, where practical, with valves for cleaning, leak testing, and backflushing.
- h. Provisions to preclude unauthorized access shall be included in the design of the intake structure.
- i. Where it is deemed necessary, practices to control zebra mussels or other aquatic nuisances must be implemented. Specific methods to control aquatic nuisances must be approved by KDHE prior to their implementation.

6. OFF-CHANNEL RESERVOIRS – These are facilities into which water is diverted during periods of high stream flow for future release to treatment facilities (or for low flow augmentation). Off-channel reservoirs shall be constructed to assure that the water quality is protected by controlling runoff into the reservoir, dikes are structurally sound and protected against wind action and erosion, and the point of influent flow is separated from the point of withdrawal.

D. GROUNDWATER – RESOURCE FACILITIES AND OTHER REQUIREMENTS

Groundwater sources include water from drilled, bored, or driven wells and infiltration lines, not under the direct influence of surface water. Drilled wells are preferred. Springs are considered surface water sources (Section C). Sources most likely to be under the direct influence of surface water (GWUI) include infiltration lines, horizontal collector wells, and shallow wells with screen openings less than 50 ft. (15 m) deep and located within 200 ft. (61 m) of surface water. Under the SWTR, all GWUI must be treated like surface water (Chapter V, Section M on Disinfection).

All water obtained from wells shall be disinfected and filtration employed where needed (Chapter V, Section M on Disinfection). The extent of water treatment required will be determined on the basis of geological data, well construction features, nearby sources of contamination, laboratory analyses, and MCLs. When a well draws water from creviced limestone strata and it is evident that the limestone supply is contaminated, the use of that supply cannot be considered appropriate unless the water is properly treated, in part by clarification and filtration, to eliminate harmful contaminants.

1. SANITARY SURVEYS – By means of a sanitary survey, the PWSS evaluates the potential threats to a proposed well presented by nearby sources of contamination. This allows the PWSS to estimate costs to reduce or contain threats to the proposed well by contaminant sources identified in the survey. Sanitary surveys made for selection of locations for wells should consider the following items:
 - a. Character of local geology, size and topography of catchment area, and slope of ground surface, as such factors relate to the potential transport of contaminants toward the well.
 - b. Nature of soil and underlying porous strata whether clay, sand, gravel, or rock (especially porous limestone); and coarseness of sand or gravel, thickness of water bearing stratum, depth to water table, and location and log of wells in the vicinity that are in use and/or abandoned, as such factors relate to the potential transport of contaminants towards the well. Geologic data should be obtained for new wells at 5 ft. (1.5 m) intervals and at each pronounced change in formation along with other pertinent well drilling information. KGS maintains a Well Sample Library in Wichita.

- c. Slope of water table, as determined from observation wells, preferably, or from studies of wells in the area.
- d. Extent of drainage area likely to contribute water and potential contaminants to the supply, population of drainage area, and waste disposal methods employed in the drainage area.
- e. Susceptibility of the proposed well location to flooding from nearby surface waters as indicated by the boundaries of flood plain delineations or historical high water elevations.
- f. Nature, distance, and direction of potential local sources of pollution such as animal feedlot operations, sanitary landfills, seepage pits, cesspools, septic tank lateral fields, privies, sink holes, salt or brine supplies, test holes, abandoned wells, borings, and chemical manufacturing, handling, and storage facilities, including underground storage tanks, pipelines for industrial products, and industrial lagoons.
- g. Special care should be taken to determine nitrate sources in the proposed well's recharge area and to evaluate fully the nitrate concentration in the aquifer in which the well will be completed. In addition to nitrate sampling of test holes in the immediate vicinity of the proposed public water supply well, other sources of information that should be considered include data from irrigation wells or other water supply wells in the general vicinity, KGS bulletins assessing the geology and hydrology of the region, and data from the KDHE Groundwater Quality Monitoring Network. The nitrate level in the aquifer in which the well will be completed should be significantly less than the current nitrate MCL unless blending with other low nitrate water or treatment for nitrate removal will be provided.
- h. The SWA conducted for the PWSS under SWAP shall be reviewed as part of the sanitary survey when determining the sources of real or potential contamination. The SWA shall be updated as is necessary based on the findings of the sanitary survey.

2. LOCATION AND PROTECTION OF WELLS – Groundwater sources shall be located, constructed, and maintained in a manner which will assure minimal possibility of contamination and be so situated and developed as to prevent surface water from entering the well. During the installation of the well, the contractor shall provide protection to prevent tampering or accidental entrance of foreign materials. The following are specific siting limitations for new wells.

- a. There must be an absence of pollution sources within 100 ft. (30.5 m) of the well. Documentation must be provided to confirm the absence of such sources. Either ownership or a perpetual easement must be obtained by the

owner of the well for the land within 100 ft. (30.5 m) measured horizontally outward from the well center. In either case, positive assurance is to be provided that no septic tanks, wastewater facilities, sanitary sewers, force mains, or tile absorption fields will be allowed within that area.

The owner may use the land for agricultural or pasture purposes except that livestock must be kept at least 100 ft. (30.5 m) away from the well. Use of the land for any purpose shall not significantly contribute to pollution of the source water. Sanitary sewers to serve residential areas outside the 100 ft. (30.5 m) wide protected zone shall transport the wastewater, either treated or untreated, to either a point downstream from the well or to a separate watershed.

If the land in question is owned by someone other than the owner of the PWSS, then a copy of a perpetual easement, detailing any limits or constraints on the use of the land by either party and showing the stamp of the Register of Deeds, must be submitted to KDHE. If the land is owned by the PWSS, then they must provide a letter to KDHE which acknowledges the ownership. Where the land in question is owned by the PWSS and other owners, the ownership letter and perpetual easements must be submitted to KDHE for the appropriate areas of land. In all cases, the documents must indicate that no potential sources of pollution will be allowed within 100 ft. (30.5 m) of the well.

- b. Proper drainage in the vicinity of the well shall be provided so as to prevent the accumulation of surface water, either by runoff or backflow, to within 100 ft. (30.5 m) of the well.
- c. Wells located on a hillside or at the foot of a hill shall be avoided where sources of pollution are present on the slope above and within 300 ft. (91.4 m) horizontally of the well. An adequate intercepting ditch shall be constructed and maintained so as to keep hillside storm water at least 100 ft. (30.5 m), measured horizontally, away from the well.
- d. The well shall not be located in a ravine where surface water flows may be obstructed or concentrated.
- e. Shallow wells with screen openings less than 50 ft. (15 m) deep shall not be located within 200 ft. (61 m) of a surface water unless treatment will be provided that fully complies with all requirements applicable to groundwater sources under the influence of surface water (Chapter V, Section M on Disinfection). On a case-by-case basis, KDHE may approve the installation of such a well without the necessity of providing such treatment, upon submittal of a report by a qualified professional establishing that, under the

particular hydrogeologic conditions, the proposed well will not be under the direct influence of any surface water.

- f. The well vent on a pitless unit or a vent in a well house or on a platform must be located at least 2 ft. (0.6 m) above the 100-year flood level to prevent contamination by flood waters. If this level is not known, then the required elevation is at least 2 ft. (0.6 m) above the highest known flood level.
- g. A wellhead protection plan for continued protection of the wellhead from potential sources of contamination shall be provided as determined by KDHE. The PWSS's sanitary survey and SWA should be reviewed as part of developing a wellhead protection plan.
- h. Additional provisions such as fencing also may be necessary to ensure the protection of the wellhead.

3. CONSTRUCTION CRITERIA FOR WELLS – The following criteria shall be followed in constructing a PWS well. Information about well abandonment is also presented. Additional design requirements for pumps and water lines are presented in Chapter VII, Pumping Facilities, and Chapter VIII, Distribution Systems.

- a. CONTRACTOR LICENSING – Any water well contractor involved in the construction or reconstruction of any public water supply well shall possess a valid water well contractor's license, issued by the KDHE under the provisions of KAR 28-30-3. All contractors shall submit to KDHE a completed water well record form WWC-5 upon construction or reconstruction of a public water supply well. A completed water well record form WWC-5P is to be submitted to KDHE when public water supply wells are plugged.
- b. DRILLING FLUIDS, ADDITIVES, AND PACKERS
 - 1) Drilling procedures or materials such as drilling fluids, additives, and packers shall not impart any taste and odor, toxic substances, bacterial contamination, or any regulated water quality contaminant to the well installation or the aquifer itself.
 - 2) Water used for drilling fluids shall be from a fresh, clean source. Only drilling fluids that will not plug the aquifer should be used. Organic drilling fluids such as those formed through the addition of polymeric additives have the potential to enhance biological activity within the aquifer and are not approved for use.
 - 3) When drilling fluid additives are used, the properties of the drilling fluid shall be maintained within those limits that will allow for the

complete removal of the additives from the well without adversely affecting hydraulic capacity, pumping efficiency, or water quality.

c. TEMPORARY SEALING REQUIREMENTS

- 1) During construction, a temporary means of sealing the well shall be provided to prevent debris or any type of contaminant from entering the well or the annular space.
- 2) Wells without an installed pump shall be securely sealed until the setting of the pump or the plugging of the well upon its abandonment.
- 3) A welded metal plate or a threaded cap is the preferred method for the temporary sealing of a well.

d. WELL CASING

- 1) All wells shall have durable watertight casing from at least 1 ft. (0.3 m) above finished ground surface to the top of the producing zone of the aquifer. The casing shall extend at least 20 ft. (6.1 m) below the ground surface.
- 2) All casing material shall be new and conform to the types, manufacturing standards, and minimum diameter requirements specified in AWWA Standard A100. Minimum wall thickness requirements for steel well casing shall conform to AWWA Standard A100. Minimum wall thickness requirements for thermoplastic well casing shall conform to ASTM F480.
- 3) Joints should be watertight and of the type specified in AWWA Standard A100.
- 4) The casing shall extend not less than 12 inches (0.30 m) above the top of the well house floor. No casing shall be cut off below the ground surface except to install a pitless unit.
- 5) The casing should be provided with sufficient guides welded to the casing to permit unobstructed flow and uniform thickness of grout.
- 6) The top of the well casing shall be sealed by installing a sanitary well seal.

e. WELL SCREEN

- 1) The well screen serves as the intake section of a water supply well, allowing the passage of water from an aquifer in unconsolidated formations such as sand and gravel. The screen also provides structural support for the surrounding formation. The screen should be designed to promote the free flow of water into the well pump area while preventing the entrance of sand.
- 2) The screen aperture size should be designed to retain a certain specified percentage of the formation material for naturally developed wells or gravel-pack material for gravel-packed wells as determined by accepted well design practices and site specific conditions.
- 3) The entrance velocity into the screen should not exceed 0.1 ft/sec (0.03 m/s) based on the maximum anticipated well flow rate or yield as determined by the following formula:

$$V_e = \frac{Q}{7.48 * A_e * L}$$

where,

- V_e = entrance velocity (ft/ min)
 Q = maximum well flow rate or yield (gpm)
 A_e = effective aperture area per foot of screen (ft²/ft)
(The effective aperture area shall be taken as one half of the total aperture area per foot of screen to allow for clogging of slots.)
 L = length of screen (ft)

KDHE will approve entrance velocities that exceed the 0.1 ft/sec (0.03 m/s) limit upon a showing that higher velocities will not impair the integrity of the well screen or result in excessive head loss.

- 4) Screen length should be determined by the thickness and hydrologic character of the aquifer, in conjunction with the determination of screen aperture size.
- 5) In some applications, other considerations such as approach velocities, turbulent versus laminar flow, and velocity distributions across the screen and through the aquifer, may require variance from the above screen design criteria.

- 6) The material from which the screen is fabricated shall be corrosion resistant and not susceptible to damage by chemical action of groundwater or cleaning operations.
- 7) Joints between screen sections and blank casing spacers should be welded or threaded, watertight, straight, and as strong as the screen.
- 8) Guides should be placed above and below all screen sections to hold the screen in the center of the borehole.

f. GRAVEL PACK

- 1) Gravel pack is installed in the annular space between the screen (and casing) and bore hole for the purpose of stabilizing the formation.
- 2) Gravel pack should consist of smooth, well rounded particles, at least 95 percent siliceous material with an average specific gravity of not less than 2.5. Before placement, the gravel pack should be washed and free of shale, mica, clay, dirt, loam, and organic impurities of any kind, and contain no iron or manganese in a form or quantity that will adversely affect the water quality.
- 3) Gravel pack design should be based on the ratio of the grain size of the gravel pack to the formation material and sized to stabilize the native formation and yet allow water to be produced from it as determined by accepted well design practices and site specific conditions. The gradation of the gravel pack should be selected after test hole samples of the formation material to be screened have been sieved and analyzed pursuant to ASTM C136.
- 4) The gravel pack should be placed in a continuous layer of material surrounding the entire screen without bridging or voids and should extend above the screen to a height sufficient to compensate for potential settlement of the gravel pack during well development. Placement of the gravel pack should also provide a sufficient buffer between the well intake and the annular seal above. The minimum thickness of gravel pack to allow for proper placement of the gravel pack in the annulus around the screen is 4 inches (10.2 cm).
- 5) Gravel pack shall be disinfected immediately prior to placement in the annulus of the well by immersing the gravel pack in a chlorine solution containing a final free available chlorine concentration of at least 200 mg/L. An acceptable chlorine solution may be prepared as described below in Subsection D.3.k.2.

- 6) The installation of gravel pack refill pipes is approved by KDHE where excessive loss of gravel pack is anticipated to occur due to formation conditions. Gravel pack refill pipes shall be Schedule 40 steel and located in the grouted annular opening of the well, surrounded by a minimum of 1.5 inches (3.8 cm) of grout. Gravel pack refill pipes shall be incorporated within the pump's concrete foundation, and extend at least 12 inches (0.3 m) above the pump house floor or concrete apron. To prevent contamination of the well, the gravel pack refill pipe shall be provided with a securable access lid or cap designed to completely cover the opening of the pipe and provide a watertight seal.

g. GROUTING OF ANNULAR SPACE BETWEEN THE CASING AND DRILL HOLE

- 1) Wells shall be sealed by grouting the annular space between the casing and the well bore from ground level to a minimum of 20 ft. (6.1 m) or to a minimum of 5 ft. (1.5 m) into the first clay or shale layer, if present, whichever is greater. If a pitless well unit is being installed, the grouting shall start below the junction of the pitless well unit where it attaches to the well casing and shall continue a minimum of 20 ft. (6.1 m) below this junction or to a minimum of 5 ft. (1.5 m) into the first clay or shale layer, if present, whichever is greater.
- 2) To facilitate grouting, the grouted interval of the well bore shall be drilled to a minimum diameter at least 3 inches (7.6 cm) greater than the maximum outside diameter of the well casing. If a pitless well unit is being installed on the well's casing, the well bore shall be a minimum diameter of at least 3 inches (7.6 cm) greater than the outside maximum diameter of the well casing through the grouted interval below the junction of the pitless well unit where it attaches to the well casing.
- 3) Protection from leakage of grout into the gravel pack or well screen shall be provided.
- 4) Waters from two or more separate aquifers shall be separated from each other in the bore hole by sealing the bore hole between the aquifers with grout or other material specifically approved by KDHE.
- 5) If a dummy casing is to be retained, the annular space between the dummy and the well casings shall be filled with grout having a minimum thickness of 1.5 inches (3.8 cm) to a minimum grout depth

of 20 ft. (6.1 m). In addition, the annular space between the dummy casing and well bore shall be grouted as specified in this chapter.

- 6) Sand-cement grout or neat cement grout shall be used for grouting the annular space from ground level to 20 ft. (6.1 m) below the surface, or, if a pitless well unit is being installed, from the junction of the pitless well unit with the well casing to 20 ft. (6.1 m) below the unit.
 - a) "Sand-cement grout" means a mixture consisting of one 94 lb (43 kg) bag of portland cement (ASTM C150) to an equal volume of sand having a diameter no larger than 0.080 inches (2 mm) to 5 to 6 gallons (19 to 23 L) of water.
 - b) "Neat cement grout" means a mixture consisting of one 94 lb (43 kg) bag of portland cement (ASTM C150) to 5 to 6 gallons (19 to 23 L) of water. A maximum of 5 percent, by weight, of bentonite may be added. Other additives may be used only with KDHE approval.
 - c) Water used to mix cement grout should be clean, fresh water, free of oil or other organic material, and with a total dissolved mineral content less than 2,000 parts per million. High sulfate water should be avoided.
 - d) Care should be exercised to control the heat of hydration during grouting where thermoplastic well casing has been installed. Additives that tend to significantly increase the heat of hydration are not recommended.
- 7) For PWS wells, KDHE does not recommend the use of annular seals consisting solely of bentonite clay grouts because of concern whether bentonite seals have sufficient shear strength to resist hydrostatic forces in certain aquifer systems. Bentonite clay grouts are approved for grouting the annular space in a well for depths greater than 20 ft. (6.1 m) from the surface or greater than 20 ft. (6.1 m) below the junction of a pitless well unit with the well casing, where the initial 20 ft. (6.1 m) length of annular space will be sealed with a sand-cement or neat cement grout.
 - a) "Bentonite clay grout" means a mixture consisting of water and commercial grouting sodium bentonite clay as per the manufacturer's recommendations to achieve a weight of not less than 9.4 lb (4.3 kg) of bentonite clay per gallon (3.8 L) of mix. Weighting agents may be added as per the manufacturer's recommendations.

- b) Sodium bentonite pellets, tablets, chips, or other granular forms of sodium bentonite are acceptable as an annular seal at depths greater than 20 ft. (6.1 m) provided the material can be installed without bridging or voids and it meets the 9.4 lb (4.3 kg) of bentonite clay per gallon (3.8 L) mix requirement.
- c) Sodium bentonite products that contain low solids, are designed for drilling purposes, or that contain organic polymers shall not be utilized for grouting the annular space of a well.

h. PLUMBNESS AND ALIGNMENT REQUIREMENTS

- 1) The completed well shall be sufficiently plumb and straight so that there will be no interference with the installation, alignment, operation, or future removal of a pump.
- 2) Every well should be tested for plumbness and alignment in accordance with AWWA standards.
- 3) The test method for plumbness and alignment and allowable tolerance shall be clearly stated in the construction specifications for the well.

i. DEVELOPMENT

- 1) Every well shall be developed to remove the native silts and clays, drilling mud, and the finer fraction of the gravel pack.
- 2) The construction specifications for the well shall provide for the application of appropriate well development techniques for the optimization of well efficiency and specific capacity. The specifications should further define criteria for determining satisfactory completion of well development. In general, development should continue until the optimum specific capacity is obtained from the completed well. Additional criteria for determining completion of well development may include a limit on sand content. If so, a method for measuring sand content should be specified.
- 3) Records of all development work should be maintained including measurements, at appropriate time intervals, of key parameters such as static and pumping water levels, production rates, specific capacity, sand content, specific conductance, temperature, etc.

- 4) Where chemical conditioning is required, the construction specifications for the well shall include provisions for the method, equipment, chemicals, testing for residual chemicals, and disposal of wastes, disinfectant solutions, and inhibitors.

j. WELL CAPACITY TESTS

- 1) Yield and drawdown tests shall be performed on every public water supply well prior to placement of the permanent pump in order to verify the pumping rate and the capability of the well and aquifer to maintain this production level. The test methods and data reporting requirements shall be clearly described in the construction specifications for the well.
- 2) Well capacity tests should be conducted only after development of the well has been completed satisfactorily.
- 3) During the tests, the discharge of the pump shall be conducted beyond the potential zone of influence of the well by pipeline or lined channel.
- 4) A constant-discharge test that consists of continuously pumping the supply well at a rate that is at least as high as the long-term production rate required of the well should be conducted. Water level measurements should be obtained before, during, and after the pumping test in order to determine the static water levels, to evaluate the effect of pumping, and to determine a profile of the recovery of the water level from the pumping state to the original, static level. The measurement frequency of water levels during pumping should be such that an adequate delineation of the time-drawdown relationship can be obtained. Additional well capacity tests such as a step drawdown tests are recommended.

k. DISINFECTION – KDHE procedures for disinfecting gravel-packed wells and completed wells, whether new, modified, or reconditioned, are as follows:

- 1) All drilling waters used during the construction or reconstruction of any water well shall be disinfected immediately prior to any drilling by thoroughly mixing with these waters enough sodium hypochlorite to produce a free available chlorine concentration of at least 200 mg/L. Mixing of additional sodium hypochlorite with drilling waters may be required to maintain a minimum free available chlorine concentration of at least 200 mg/L while drilling is in progress.

- 2) Gravel for gravel-packed wells shall be disinfected immediately prior to placement by immersing the gravel in a chlorine solution prepared using clean water having a final free available chlorine concentration of at least 200 mg/L. A satisfactory chlorine solution may be prepared by thoroughly dissolving approximately 5 oz (142 g) of high test calcium hypochlorite (65 percent available chlorine) in every 100 gallons (380 L) of water.
- 3) Completed wells, after development, shall be disinfected by mixing with the water in the well enough of a pre-mixed calcium hypochlorite solution to produce a free available chlorine concentration in the well of at least 100 mg/L. This will require thoroughly dissolving in clean water approximately 1.5 lb (0.68 kg) of high test calcium hypochlorite (65 percent available chlorine) for each 1,000 gallons (3,800 L) of well volume that is occupied by water.
- 4) Just prior to setting the pump, the pump and the pump column shall be washed down with a chlorine solution having an initial free available chlorine concentration of at least 200 mg/L. An acceptable chlorine solution may be prepared as described above in Subsection D.3.k.2.

I. ABANDONED WELLS AND TEST HOLES – Before any well or test hole drilled in connection with a water supply is abandoned, it shall be plugged in such a manner as to prevent the pollution of the groundwater by contaminating substances. Abandoned water wells and test holes, whether cased or uncased, shall be plugged in accordance with the requirements of KAR 28-30-7.

m. HORIZONTAL COLLECTOR WELLS

- 1) General – HCWs will generally be reviewed on the same basis as other PWS wells are reviewed except that a comprehensive siting study must be completed and a copy of the findings submitted to KDHE for review. Given their unique design, the review and approval of HCWs and their ancillary items will be on a case-by-case basis.
- 2) Caisson
 - a) Construction joints and porthole assemblies shall be indicated.

- b) Wall shall be reinforced to withstand the forces to which it will be subjected.
- c) Caisson shall be continuously monitored for trueness to vertical during the forming, pouring and sinking processes.
- d) Caisson cutting shoe design shall be illustrated.
- e) Lateral collectors shall be in areas and at depths to maximize flow into the caisson.
- f) Lateral screen design shall permit maximum flow with minimal fouling.
- g) Lateral collectors shall be horizontal.
- h) Caisson opening shall be covered with a watertight floor.
- i) All openings in the floor shall be curbed and protected from the entrance of foreign material.
- j) Routing of pump discharge piping through the caisson walls will not be approved. However, where circumstances make this requirement infeasible, a watertight seal must be installed at the caisson wall.
- k) A monitoring and maintenance program for caisson laterals shall be developed and implemented to maximize the useful life of the HCW.

3) Ancillary Items

Pumping, treatment, water lines and related appurtenances shall be according to the requirements of Chapters V, VII, VIII and IX.

n. RECONSTRUCTED WELLS AND RELATED APPURTENANCES

- 1) Reconstructed wells and their related appurtenances must meet the requirements for PWS wells as stated in this chapter.
- 2) Original well construction drawings or well construction drawings based on field investigations when original well construction drawings do not exist must be part of the documentation submitted to KDHE for its review and approval.

- 3) Where well reconstruction includes the insertion of one or more casing/screen assemblies into an existing well, the required grout and gravel pack thicknesses stated in this chapter shall apply to all bore hole-to-casing and casing-to-casing annular spacing. Requirements for the construction of PWS wells pertaining to well casings as stated in this chapter shall apply to all casings.
 - 4) Requirements for PWS wells pertaining to water rights, wellhead protection, development, disinfection, etc. as stated or referenced in this chapter shall also apply.
4. CONSTRUCTION CRITERIA FOR WELL HOUSES, DISCHARGE PIPING, AND RELATED APPURTENANCES – The following criteria for the construction of well houses and for discharge piping and related appurtenances must be followed. Additional design requirements for pumps are presented in Chapter VII, Pumping Facilities.

a. GENERAL WELL HOUSE REQUIREMENTS

- 1) The well house shall be provided with a doorway and a door at least 2 ft. 8 inches (0.8 m) by 6 ft. 8 inches (2.0 m) which opens outward and extends to the floor. The door shall be equipped with a lock.
- 2) Well houses located on hill slopes shall have not less than 50 percent of the floor area above ground level and the door located on that part of the floor above ground level.
- 3) The well house walls and ceiling shall be insulated.
- 4) Where necessary, additional protection against freezing shall be provided by installing a thermostatically controlled electric heater or other suitable type of heating unit.

b. WELL HOUSE FLOOR

- 1) The well house floor elevation shall accommodate the well vent elevation requirement that the vent be located at least 2 ft. (0.6 m) above the 100-year flood level. If this level is not known, then the required vent elevation is at least 2 ft. (0.6 m) above the highest known flood level.
- 2) The top of the floor slab shall not be less than 1.5 ft. (46 cm) above the natural ground.

- 3) The well house floor shall be constructed of reinforced, watertight concrete not less than 4 inches (10.2 cm) thick at any point.
- 4) The joint between the concrete base that supports the pump discharge head assembly and the floor shall be watertight. The concrete base that supports the pump discharge head assembly shall be extended to natural ground to provide solid support.
- 5) The floor shall extend not less than 3 ft. (0.9 m) in all directions from the outer edge of the drill hole.
- 6) The floor slab shall rest upon thoroughly compacted earth or upon a protected settled sand fill. Consideration should be given to the frost line prior to preparing the ground that will support the floor slab and the concrete base that will support the pump discharge head assembly.
- 7) The floor shall slope at a rate of 1/8 in/ft (1.0 cm/m) toward the floor drain.

c. FLOOR DRAIN

- 1) A minimum 4 inch diameter (10.2 cm) floor drain with a perforated or screened cover shall be provided.
- 2) The drain pipe shall carry the drain water to the ground surface at least 20 ft. (6.1 m) from the well or at least 4 ft. (1.2 m) from the well house wall at which point the pipe may be connected to other suitable 4 inch diameter (10.2 cm) pipe so that the drainage will be carried to the ground surface at least 20 ft. (6.1 m) from the well.
- 3) The drain pipe shall be laid on a grade of not less than 1/8 in/ft (1.0 cm/m) and shall discharge onto the surface of the ground. The drain shall not be connected to any storm drain, sanitary sewer, or any other closed conduit. The discharge end of the drain line should be covered with a coarse non-corrodible screen to prevent the entrance of small animals.

d. CASING SEAL AND DISCHARGE PIPING

- 1) The casing shall extend at least 1 inch (2.5 cm) up into the metal base plate of the pump discharge head assembly so as to form an overlapping seal. For pump discharge head assemblies that have a flat metal base plate or radial ribs that will interfere, a metal skirt projecting downward may be welded to the outside edge of the metal

base plate of the pump discharge head assembly to form a cover that will overlap the well casing.

- 2) The metal base plate of the pump discharge head assembly shall be grouted and bolted or otherwise securely sealed to the concrete base that supports the pump discharge head assembly so as to be watertight.
- 3) The discharge line, meter, and check and shutoff valves shall be located above the well house floor.

e. WELL VENT

- 1) The vent shall be constructed of metal tubing or pipe and fitted through the pump head's metal base plate so as to form a watertight connection with the base.
- 2) The vent shall terminate in a full 180° return bend not less than 2 ft. (0.6 m) above the pump base.
- 3) The opening in the vent shall be screened with 16-mesh non-corrodible screen.

f. WATER LEVEL MEASUREMENT

- 1) Provisions shall be made for the periodic measurement of water levels in the completed well in accordance with the requirements established by DWR in KAR 5-6-13 for water well level measurement (DWR, 1999). The following water level measurement methods are approved for public water supply wells:
 - a) Air line method;
 - b) Separate observation well within 25 ft. (7.6 m) of the production well; or
 - c) Electronic water level measurement sensors.

A separate tube installed outside the casing for use of a tapeline drawdown measurement is prohibited.

- 2) Air Line Method – The air line method measures depth to water level by determining the air pressure required to push water out of a submerged tube of known length. The air line tube shall be constructed of corrosion-resistant materials and pass down through

the pump head's metal base plate and into the well casing so as to be continuously within the inside diameter of the well casing in a manner that will provide for a watertight seal between the casing and the pump head's metal base plate, i.e., a watertight packing gland or equal shall be provided around the casing where it passes through the pump head's metal base plate. For wells with a submersible pump, the air line shall be continuously within the inner diameter of the well casing and sealed at the top of the well as described above to preclude contamination. To avoid turbulence near the intake of the pump, the lower end of the air line should be several feet above or below the point where water enters the pump but still extend below the lowest possible pumping level. The upper end of the tube shall be fitted with suitable connections for an air gauge, valve, and air pump. The actual installed length of air line shall be indicated on a pump head's metal base plate in the immediate vicinity of the well.

g. VALVES AND OTHER APPURTENANCES

- 1) Pump Discharge Line – The pump discharge line shall be equipped with a check valve, a shutoff valve, and a standard pressure gauge.
- 2) Air/vacuum Relief Valves – Combination air/vacuum relief valves may be required where air is forced into the pump discharge line through the pump resulting in decreased efficiency and possibility of surges within the lines. These valves are potential sources of contamination to the water supply because contaminants can be drawn into the water supply on the vacuum relief cycle.

The vent discharge lines from combination air/vacuum relief valves on pump discharge lines should terminate in a downward position about 2 ft. (0.6 m) above the floor of the well house. If splashing is a problem, a loose fitting "splash guard" may be used. The end of the vent discharge line should be screened with 16-mesh non-corrodible screen. In no case should the vent discharge line be tightly connected to the floor drain. Air/vacuum relief valves on pump discharge lines should be located on the pump side of the check valve and meter.

Where water hammer is problematic, combination air/vacuum relief valves with slow-closing devices or air-throttling devices incorporated into their valve design may be installed to minimize water hammer effects. Installation of such devices near the pump is critical to their effectiveness.

- 3) Meters – Meters shall be provided for all wells. Meters shall meet the requirements established by DWR in KAR 5-1-4 et seq. (DWR,

2004). Meters should be located on the pump discharge line and on the pump side of a shutoff valve but after the air/vacuum relief valve and check valve.

- 4) Sampling Taps – Sampling taps are required on the discharge side of a pump at locations both upstream and downstream from where chlorine (or any other treatment) is applied to the pump's discharge piping. The upstream sampling tap is for collecting untreated well water samples while the downstream sampling tap is for collecting samples for measuring chlorine residuals (or other necessary measurements, including those pertaining to other types of treatments). In general, a separation distance of at least 10 ft. (3.0 m) should be maintained between the point at which chlorine (or any other treatment) is applied to the discharge piping and the location of the downstream sampling tap to ensure complete mixing prior to sampling. However, a greater separation distance or a post-application static mixer may be required depending on the degree of mixing in the pipe at and downstream of the point of application.

The piping layout in most well houses does not provide a separation distance of at least 10 ft. (3.0 m), therefore, the downstream sampling tap may have to be located beyond the foot print of the well house and its associated sampling line extended back into the well house in order to ensure complete mixing prior to sampling. Alternatively, a static mixer may be located between the point where the chlorine (or any other treatment) is applied and the location of the downstream sampling tap to ensure complete mixing prior to sampling.

When the discharges of two or more wells are combined into a common header pipe prior to treatment at a central location, their respective upstream sampling valves shall be upstream of the points where their respective well discharge piping connects to the common header pipe and upstream of any treatment provided.

It is desirable to provide a valve in the sampling line between the wellhead piping and the sampling tap or hose bib so that the tap (or hose bib) can be repaired or replaced without depressurizing any portion of the system.

- 5) Chemical Injection – All points of chemical addition shall be no earlier than downstream of the check valve, and preferably after the flow meter and other appurtenances to both prevent direct feed of chemicals to a well and to minimize corrosion of the flow meter and other chemical sensitive appurtenances. The use of in-line static mixers is encouraged to ensure adequate mixing prior to sampling.

5. CONSTRUCTION CRITERIA FOR PITLESS UNITS AND RELATED APPURTENANCES

- a. **APPROVAL CRITERIA** – The use of pitless units for public water supply wells for below ground discharge is approved. Pitless “adapters,” those devices utilized in conjunction with a modification to the wall of the well casing (e.g., a hole) for the purpose of providing a connection between the discharge pipe and the well casing, are not approved for this purpose. A pitless unit is designed and shop-manufactured to be a complete unit that can only be attached to the top of the well casing to form a continuous, unbroken extension of the casing to at least 1 ft. (0.3 m) above the finished ground surface. The connection shall be at an elevation that is below the frost line.

The pitless unit may be for either submersible pumps or for deep well type turbine pumps and must permit the pumps to be readily removed. The pitless unit material of construction shall be compatible with the casing. The inside diameter of the pitless unit should be equal to that of the casing up to and including a diameter of 1 ft. (0.3 m) to facilitate making repairs to the well, pump, or well screen. KDHE approval is required for any connection where the diameter of the pitless unit differs from that of the casing. The drop pipe shall be attached by a threaded fitting at an elevation that is below the frost line.

- b. **LIMITATIONS ON FIELD WELDING** – If the connection to the casing is to be an in-the-field weld, the shop-manufactured and assembled pitless unit must be designed specifically for this method of connecting the pitless unit to the top of the well casing pipe. The only field welding permitted will be that which is needed to connect a pitless unit to the top of the well casing pipe with the resultant weld being a continuous, watertight weld.
- c. **CONCRETE SLAB** – In lieu of a well house, a reinforced concrete slab not less than 4 inches (10.2 cm) in thickness and extending 3 ft. (0.9 m) beyond the well bore in all directions shall be provided. The slab shall form a watertight joint with the pitless unit. The slab should preferably be placed at the ground finish grade, 1.5 ft. (46 cm) minimum above the natural ground, and shall slope away from the casing. The concrete slab shall be designed and constructed to withstand alternating freezing and thawing conditions. Approval may be given for placement of the slab below the pitless unit and below ground level. Where a pitless unit is used, a protective railing or steel posts shall be provided in such a manner that the pitless unit will not be damaged by machinery or farm animals. Appurtenances such as meter pits, frost free valves, etc., may be integral to the slab so long as they are located at least 3 ft. (0.9) beyond the outer diameter of the well bore and are appropriately curbed and drained.

d. APPURTENANCES

- 1) Check Valve – There shall be at least one check valve within the well casing. Check valves for these types of wells are typically located in a spool piece which is utilized to join the pitless unit and the casing, the drop pipe, or integral to the submersible pump.
- 2) Sanitary Well Seal – The top of the pitless unit shall be securely fitted with a sanitary well seal, which creates an air and watertight seal. The pitless unit shall also be designed to receive a contamination-proof conduit for power purposes.
- 3) Well Vent – The pitless unit shall be fitted with a vent, which shall terminate in a full 180° return bend. The elevation of the well vent shall be not less than 2 ft. (0.6 m) above the 100-year flood level. If this level is not known, then the required vent elevation is at least 2 ft. (0.6 m) above the highest known flood level. The opening in the vent shall be screened with 16-mesh non-corrodible screen.
- 4) Water Level Measurement – Provisions shall be made for the periodic measurement of water levels in the completed well in accordance with the requirements established by DWR in KAR 5-6-13 (DWR, 1999). Tubes or cables, required for measurement of water levels, shall be installed through special fittings in the watertight cap in a manner to prevent the entrance of surface water or other contaminants within the well casing.
- 5) Meters – Each well must be provided with a meter and it shall meet the requirements established by DWR in KAR 5-1-4 et seq. (DWR, 2004). Meter boxes or vaults should be constructed with crushed rock bottoms (French drains) to permit adequate drainage, and located and covered so as to minimize the entrance of surface water. A shut-off valve to isolate the meter to facilitate testing and repairs or replacement should be located downstream from the meter. Meter pits, boxes or vaults integral to a pitless unit's surface slab shall be located at least 3 ft. (0.9 m) beyond the outer diameter of the well bore and be appropriately curbed and drained.
- 6) Sampling Taps – The well's design shall include a sampling tap to collect raw water samples from the well or its discharge piping upstream of where chlorine (or any other treatment) is applied to the well's discharge piping. The design shall also include a sampling tap downstream of where chlorine (or any other treatment) is applied to the well's discharge piping for the purpose of collecting samples for measuring chlorine residuals (or other necessary measurements,

including those pertaining to other types of treatments). As outlined above in Section D, Subsection 4.G.4, a separation distance of at least 10 ft. (3.0 m) should be maintained between the point at which chlorine (or any other treatment) is applied to the discharge piping and the location of the downstream sampling tap to ensure complete mixing prior to sampling. However, a greater separation distance or a post-application static mixer may be required depending on the degree of mixing in the pipe at and downstream of the point of application.

When the discharges of two or more wells are combined into a common header pipe prior to treatment at a central location, their respective upstream sampling valves shall also be upstream of both where their respective well discharge piping connects to the common header pipe and where any treatment is applied to the combined flow in the header pipe.

It is desirable to provide a valve in the sampling line between the wellhead piping and the sampling tap or hose bib so that the sampling tap (or hose bib) can be repaired or replaced without depressurizing any portion of the system.

Sampling appurtenances such as meter pits, vaults, frost free valves, etc., integral to a pitless unit's surface slab shall be located at least 3 ft. (0.9 m) beyond the outer diameter of the well bore hole and be appropriately curbed and drained.

CHAPTER V

DESIGN OF WATER TREATMENT PROCESSES

A. INTRODUCTION

This chapter describes considerations involved in the design of water treatment processes. Through appropriate selection and design of individual processes and their integration into treatment sequences to suit the nature and quality of the raw water supply, and with good operating practices, it is possible to produce finished water for consumers that will comply fully with the biological, chemical, physical and radiological quality requirements of Kansas drinking water regulations. The National Primary Drinking Water Standards adopted by Kansas to date are referenced by the appropriate Kansas Administrative Regulation (KAR) designations. Those National Primary Drinking Water Standards that have not yet been adopted are referenced with the appropriate Code of Federal Regulations (CFR) designations, which will be superseded by the appropriate KAR designations as these standards are adopted.

The requirements of the drinking water regulations consist of MCLs and treatment techniques. These requirements and the analytical methods for measuring contaminant levels are summarized in KAR 28-15 and KAR 28-15a. Primary MCLs and treatment technique requirements are related to public health and are enforceable whereas secondary MCLs (SMCLs) address aesthetic qualities relating to the public acceptance of drinking water and are not enforceable. A treatment technique requirement is established instead of an MCL when routine monitoring of one or more contaminants is not economically or technologically feasible.

The USEPA designates best available technologies (BATs) for the purpose of: 1) demonstrating that a technology exists to achieve compliance with a particular MCL or treatment technique requirement; 2) providing a basis for estimating the cost associated with a particular regulation, thereby demonstrating that the costs are reasonable (relative to the benefits, at least for a typical large PWSS); and 3) to serve as a basis for granting variances (time extensions). PWSSs may use other treatment technologies to comply with an MCL or treatment technique requirement, if approved by the reviewing authority, but must use BAT or an equally effective technology when applying for a variance.

Kansas drinking water regulations are based on federal regulations promulgated by USEPA under the authority of the SDWA. KDHE will revise the Kansas regulations when the federal drinking water regulations are revised. Therefore, PWSSs should stay abreast with these changes, anticipate their impact on the ability of existing treatment facilities to comply with the primary drinking water regulations (i.e., both MCLs and treatment techniques), and plan to upgrade facilities when necessary. In undertaking this task, PWSSs should consider

alternate water sources and phased construction of process trains so that additions or changes can be made with minimal interruption to the treatment system and at a lower cost to the PWSS.

In some cases, a new treatment technology, for which KDHE has not developed specific design requirements, may be the best option for achieving compliance with a particular MCL or treatment technique, especially one that has been recently promulgated. Requirements for approval of such processes are described in Subsection A.5 of Chapter III.

B. OVERVIEW OF DESIGN REQUIREMENTS FOR MEETING THE PRIMARY DRINKING WATER REGULATIONS

1. GENERAL REQUIREMENTS – The design engineer generally has a number of treatment options to choose from, but at a minimum the treatment system must include those processes needed to produce water in compliance with the regulations. Treatment process requirements depend on:
 - a. The type of system and, in some cases, the number of customers served;
 - b. Whether the contaminants being removed are MCL- or treatment-technique-controlled (Section A); and
 - c. The requirements of the current drinking water regulations.
2. VOC REMOVAL
 - a. If the concentration of a VOC will exceed its MCL (KAR 28-15a-61) in the absence of treatment, a community or non-transient non-community system must implement the necessary treatment to reduce the concentration of the VOC to a level that is less than its respective MCL.
 - b. The BATs for all VOCs except vinyl chloride are packed-tower air stripping (Section P) and adsorption on GAC (Section Q). Packed-tower air stripping is the only BAT for vinyl chloride.
3. FLUORIDE CONTROL
 - a. The American Dental Association endorses fluoridation of community water supplies as being safe and effective for preventing tooth decay. The beneficial level of fluoride is known to be approximately 1 mg/L. Public water supply systems with a properly designed and operated fluoridation system (Section T) can readily comply with both the MCL and the SMCL for fluoride, 4 mg/L and 2 mg/L, respectively (KAR 28-15a-62)(40 CFR 143.3). Where the level of fluoride is excessive, treatment is required to meet the MCL and encouraged to meet the SMCL.

- b. A BAT has not been specified for fluoride removal. Central treatment using activated alumina adsorption (Rubel, 1984) or reverse osmosis (Section S) is an option for fluoride removal; and excess-lime softening (Section K) can be used to remove fluoride from hard waters containing an adequate concentration of magnesium. Design requirements for activated alumina adsorption are described in Section R; but due to the lack of experience with this process in Kansas, it will be treated in the same manner as a new process (Subsection A.5 of Chapter III).

4. FILTRATION AND DISINFECTION FOR PATHOGEN REMOVAL AND INACTIVATION – The treatment techniques of filtration (Section J) and disinfection (Section M) are used, in addition to the MCL for coliforms (KAR 28-15a-63), to ensure the microbiological quality of drinking water and to specifically address *Giardia*, *Cryptosporidium*, *Legionella*, HPC bacteria, viruses, and turbidity (KAR 28-15a-21, 70-76, 170-175)(40 CFR 141.400 et seq.)(40 CFR 141.600 et seq.)(40 CFR 141.700 et seq.).

- a. Disinfection is required for all PWSSs (KAR 28-15-19). All PWSSs that use surface water or GWUI must provide pathogen removal and inactivation by means of filtration and disinfection (KAR 28-15a-70), respectively.
- b. A conventional filtration system (KAR 28-15a-2) consists of coagulation (Section F), flocculation (Section G), sedimentation (Section H), and filtration (Section J) followed by protected storage (Chapter VI). A conventional filtration system can also include precipitative softening to remove hardness (Section K). Non-conventional filtration options include direct filtration, slow sand filtration, and membrane processes (Section S). The performance requirements for filtration are specified in KAR 28-15a-73.
- c. PWSSs using surface water or GWUI must achieve a 3-log removal and/or inactivation of *Giardia lamblia*, a 4-log removal and/or inactivation of viruses, and a 2-log removal of *Cryptosporidium*. Additional removal or inactivation of *Cryptosporidium* may be required, depending on the quality of the source water (40 CFR 141.700). Removal credits are assigned to various filtration processes, and the balance of the required removal must be achieved by disinfection. Residual disinfectant levels must meet both minimum (KAR 28-15a-72) and maximum (KAR 28-15a-65) values. (Maximum residual disinfectant levels are referred to as MRDLs.) If a MRDL can not be met because a higher dosage is needed to maintain the required minimum residual, additional treatment will be needed to reduce disinfectant demand. The disinfection process is monitored by measuring disinfectant residuals at the plant and in the distribution system (KAR 28-15a-74 and 28-15-19); by checking CT values (Section M); and by analyzing samples of finished water at the plant and in the distribution system for coliforms (KAR 28-15a-21).

- d. No variances from the total coliform, filtration, and disinfection requirements are allowed for PWSSs using surface water or GWUI. Exemptions are allowed for all requirements except total coliforms and disinfectant residual requirements at the point of entry to the distribution system.

5. CORROSION CONTROL FOR LEAD AND COPPER

- a. Community and non-transient, non-community PWSSs are required to comply with the lead and copper rule (KAR 28-15a-80 through 91). The lead and copper rule requires PWSSs to optimize corrosion control treatment to minimize lead and copper concentrations at the users' taps while ensuring that the treatment does not cause the system to violate another primary drinking water standard (KAR 28-15a-2)(KAR 28-15a-81 through 82). All PWSSs serving more than 50,000 customers are required to conduct corrosion control studies unless they can demonstrate to KDHE that corrosion control has been optimized. For smaller PWSSs, the requirement for corrosion control studies is triggered by lead and copper action levels.
- b. Treatment technique requirements are triggered when action levels for lead and copper are exceeded and they consist of optimized corrosion control, source water treatment, public education, and replacement of lead service lines under the direct control of the PWSS. Treatment processes able to remove particulate or dissolved lead and copper from source water include coagulation and filtration (Sections F and J), lime softening and ion exchange (Section K), and membrane processes (Section S). However, elevated lead and copper concentrations in the distribution system are generally attributable to corrosion rather than to elevated concentrations in raw water, and treating the raw water may only make the problem worse if the water is not properly stabilized. Therefore, stabilization (i.e., optimized corrosion control) is expected to be not only the most appropriate treatment process but also the only effective process. Stabilization is addressed in Section L.

6. IOC AND SOC REMOVAL

- a. Community and non-transient, non-community PWSSs are required to meet the MCLs for IOCs and SOCs (KAR 28-15a-11 and 62); but the MCL for fluoride applies only to community water systems. The MCLs for nitrate, nitrite, and the sum of nitrate plus nitrite also apply to transient non-community water systems.
- b. KAR 25-15a-61 and KAR 28-15a-62 list the BATs for all IOCs and SOCs except acrylamide and epichlorohydrin (for which specific dosage limitations are specified in KAR 28-15a-111) and fluoride (for which no BAT is listed). DBPs are not regulated as SOCs and are addressed in Subsection B.8.

- c. Numerous contaminants are regulated as IOCs or SOC, and most of the processes addressed in later sections of this chapter are BATs for one or more of these contaminants. IOCs and SOC present as particles, adsorbed onto particles, or able to be incorporated into floc particles formed during water treatment can be removed by coagulation and flocculation (Sections F and G), or softening (Section K), followed by sedimentation (Section H) and filtration (Section J). Membrane processes (Section S) effectively remove particulate contaminants, and reverse osmosis can also remove many contaminants present in dissolved form.

Adsorption on GAC (Section Q) is a BAT for most of the SOC and for mercury; and packed-tower air stripping (Section P) is a BAT for the more volatile SOC. Although a number of SOC can be chemically oxidized using one or more of the chemicals used for disinfection (Section M), oxidation is specified as a BAT only for glyphosate. Oxidation of SOC usually produces byproducts; and although the byproducts are generally expected to be less toxic than the parent compounds, there is rarely enough information available to fully assess the risks they pose to human health. Therefore, physical removal of SOC is generally preferred over oxidation; however, oxidation is an effective way to address a number of organic chemicals that, in trace amounts, cause taste and odor problems (Section N) but are not toxic.

Other processes identified as BAT for selected IOCs include adsorption on activated alumina, ion exchange, and electrodialysis (Section R). KDHE considers these new processes (Subsection A.5 of Chapter III), but ion exchange systems must meet the applicable requirements for ion-exchange softening (Section K). Ion exchange and reverse osmosis are BATs for nitrate and nitrite; biological removal of nitrate and nitrite is not a BAT, but may be proposed as a new process.

Seven BATs and twelve “small system compliance technologies” have been identified for arsenic. These technologies are for removal of As(V), and pre-oxidation may be necessary to convert As(III) to As(V) (KAR 28-15a-62). A number of these technologies are new processes (Subsection A.5 of Chapter III); and some of the technologies for small systems involve point-of-use treatment, which is generally not favored over centralized treatment for a PWSS but may be economically justified for certain small systems. Additional information regarding these technologies, their removal efficiencies, and their design can be found in Section R, the final Arsenic Rule (USEPA, 2001) and in various other publications (e.g., USEPA 2000a, 2002, 2003a, and 2006b). Use of point-of-entry devices is subject to KDHE approval and the provisions of KAR 28-15a-100.

7. RADIONUCLIDE REMOVAL

- a. Community PWSSs are required to meet the MCLs for radionuclides (KAR 28-15a-66).
- b. KAR 28-15a-66 specifies BATs and small system compliance technologies for radionuclide removal. The BATs for radium 226 and 228 are lime softening (Section K), ion exchange (Sections K and R), and reverse osmosis (Section S). Radon (for which new regulations are pending) can be removed by air stripping (Section P) or adsorption on GAC (Section Q). The BATs for uranium are coagulation and filtration (Sections F and J), lime softening, ion exchange, and reverse osmosis. Reverse osmosis is the BAT for gross alpha particle activity (excluding radon and uranium); and reverse osmosis and ion exchange are the BATs for beta particle and photon activity.

Compliance technologies for small systems include the BAT processes as well as point-of-use ion exchange and reverse osmosis, electrodialysis and electrodialysis reversal, and adsorption on activated alumina or manganese-coated media (Subsection O.2 and Section R). Several of these will be considered by KDHE as new processes (Subsection A.5 of Chapter III); and use of point-of-entry devices is subject to KDHE approval and the provisions of KAR 28-15a-100.

8. DBP CONTROL AND PRECURSOR REMOVAL

- a. Community and non-transient, non-community PWSSs are required to meet MCLs for DBPs (KAR 28-15a-64); and Subpart H systems (those using surface water or GWUI) must meet treatment technique requirements for DBP precursors (KAR 28-15a-135). BAT processes for compliance with the MCLs for trihalomethanes (TTHMs) and haloacetic acids (HAA5) are enhanced coagulation and softening, adsorption on GAC (Section Q), nanofiltration (Section S) with a molecular weight cutoff of less than 1000 Daltons, and (for consecutive systems) improved distribution and storage tank management, to reduce residence time, and the use of chloramines for residual disinfection (KAR 28-15a-64).
- b. DBPs can be controlled by reducing the concentration of DBP precursors by means of source control or treatment, delaying the point of chlorine application, avoiding excessive use of chlorine and other disinfectants, using alternate disinfectants, removing DBPs after they form, using combined chlorine instead of free chlorine in the distribution system, improving distribution system and storage tank management to reduce residence time, and in some cases by adjusting pH. Practices potentially suitable for controlling precursors at the source include selective withdrawal from reservoirs, algae control, and using alternate water sources.

Treatment processes for removing precursors include coagulation (Section F), lime softening (Section K), filtration (Section J), adsorption on GAC (Section Q) or PAC (Section N), membrane processes (Section S), and chemical oxidation (Section M) followed by biological filtration (Subsection J.15). Alternate disinfectants include chlorine dioxide, ozone, and UV light (Section M). Removal of some byproducts can be accomplished using air stripping (Section P), adsorption on GAC (Section Q), and reducing or oxidizing agents.

C. DESIGN REQUIREMENTS FOR OPTIONAL TREATMENT PROCESSES

1. **INTRODUCTION** – Optional treatment processes may be used to meet the particular needs of a PWSS. Optional processes are those for which no regulatory requirement exists. They are most commonly used to remove contaminants for which SMCLs have been established (40 CFR 143.3).

Plans, specifications and a permit application for optional processes must be submitted to KDHE for review and approval prior to the start of construction and must:

- a. Identify the contaminants being removed, the treatment objectives, and the reasons for any differences between the treatment objectives and the SMCLs where the treatment objectives exceed the SMCLs;
- b. Include an appropriate basis of design (including pilot-plant data if necessary to demonstrate the effectiveness of an existing technology for a novel contaminant or the effectiveness of a new technology for a common contaminant); and
- c. Comply with all pertinent design requirements included in this document.

Considerations pertaining to several of the most commonly removed contaminants are presented in the following sections.

2. **SOFTENING**

- a. Softening is desirable for PWSSs where high levels of hardness are present. Softening may be accomplished by addition of lime alone where natural alkalinity will permit, or by addition of lime and soda ash where removal of non-carbonate hardness is desired (Section K). Softening may also be accomplished using cation exchange (Section K) and certain membrane processes (Section S).
- b. The processes used for softening also remove other contaminants, some of which are regulated and some of which are not. Fluoride, pathogens, heavy

metals (e.g., lead and copper), and certain IOC, SOC, and radionuclides are examples of regulated contaminants affected by softening. A number of contaminants for which SMCLs have been established are also affected by softening, including total dissolved solids, copper, zinc, aluminum, iron, manganese, and fluoride. Softening also influences pH and the stability of the water, which may need to be adjusted (Section L) following softening.

3. IRON AND MANGANESE REMOVAL

- a. Removal of iron and manganese is desirable for a PWSS when the source water contains iron or manganese in excess of their respective SMCLs.
- b. Common treatment processes include aeration (Section P) or chemical oxidation (Sections M and O) followed by filtration (Section J); lime softening (Section K) followed by filtration; and adsorption on manganese-coated media (Section O). Low concentrations of iron and manganese can sometimes be effectively sequestered (Section O).
- c. As in the case of hardness removal, other contaminants (especially certain IOCs) may be removed along with iron and magnesium depending on the process used.

4. HYDROGEN SULFIDE REMOVAL

- a. Removal of hydrogen sulfide is desirable for a PWSS when its odor would otherwise be present in the finished water.
- b. Treatment processes include air stripping (Sections N and P) and chemical oxidation (Sections M and N).

D. **GENERAL DESIGN CONSIDERATIONS**

1. GENERAL CRITERIA – Certain considerations should be addressed in the design of both optional and required treatment processes:
 - a. **DEGREE OF TREATMENT PROVIDED** – Required processes must achieve the required degree of treatment (based on applicable MCLs and treatment technique requirements) under the most stringent process constraints that can reasonably be anticipated. Optional treatment processes should be designed to meet the stated goals (e.g., SMCLs) under most or all anticipated water quality and operating conditions and must be designed such that the PWSS is able to provide an uninterrupted supply of potable water whether or not these goals are being met.

- b. **MINIMUM NUMBER OF UNITS** – There should be at least two units of each process so that one can be used if the other is inoperable; and this is mandatory for certain required processes, e.g., filtration and disinfection for PWSSs using surface water or GWUI.
- c. **PIPING** – Providing both series and parallel flow between units should be considered where doing so is practical and would beneficially increase the reliability of the treatment train. Where appropriate, a bypass should be provided to enable a unit to be removed from service.
- d. **FLOW RATE AND FLOW REGIME** – Internal or external flow control devices should be provided where necessary to control the rate of flow through the process. Baffling or mixing should be provided where needed to provide the desired flow regime of plug flow, complete mixing, or intermediate regimes.
- e. **CHEMICAL ADDITION** – Many treatment processes require the addition of chemicals. Both general and specific considerations are addressed in Chapter IX, Chemical Storage, Handling, and Application.
- f. **HYDRAULIC** – Head losses should be minimized to reduce energy costs but not to the point of affecting the desired flow regime or flow control; and the head requirements associated with anticipated future process additions and plant expansion should also be considered.
- g. **PROCESS CONTROL** – Automatic control of a process is often desirable, especially where it can relieve operators of mundane tasks, improve operational efficiency, improve process control, or where an operator's attention may be limited. Manual operation must always be possible where automatic controls are employed as the primary means of control.
- h. **MONITORING** – Monitoring of various water quantity and quality parameters is usually required for process control and regulatory compliance purposes. Provision should be made to collect samples and to measure and record the appropriate process and water quality variables.
- i. **CLIMATE AND WEATHER** – Many treatment units will be affected by seasonal and temporal variations in water temperature or weather conditions.
- j. **TRAINING AND SAFETY** – Operator and consumer safety must be given paramount consideration in process design. As with any existing or new technology, all necessary training for plant operators shall be provided prior to plant start-up.

- k. **ADJUSTABLE FEATURES AND FUTURE NEEDS** – The possibility of process modifications, expansions or other changes to the treatment system must be considered. These may be minor changes or adjustable features (such as alternate chemical feeding locations, adjustable mixing energy input, adjustable weirs, addition of baffles, or provisions for additional monitoring), that might improve treatment efficiency at minimal cost, or major changes such as future plant expansions involving large capital expenditures.
 - 2. **PERMIT APPLICATION** – A public water supply permit application and submission of plans and specifications to KDHE for review and approval prior to the start of construction are required for alterations or improvements involving a change in the treatment or the design capacity. A change in disinfection practice is also a change in treatment. Accordingly disinfection profiles and benchmarks (USEPA, 1999a), and CT ratio and log inactivation calculations for both the existing and proposed disinfection practice, must be submitted to KDHE for review. Changes in design capacity may be as simple as installing a larger capacity pump or as complex as addition of new infrastructure. Both would require submission of the above to KDHE for review and approval prior to the start of construction.
 - 3. **REMAINING CHAPTER ORGANIZATION** – The remaining sections in Chapter V review the design criteria for the various treatment processes used to accomplish contaminant removal or control. The sequence of processes does not follow any particular order except that those listed first are common to surface water treatment plants. Each plant will have its own unique sequence of processes depending upon site specific conditions and the preferences of the PWSS and its design engineer.
- E. **PRESEDIMENTATION** – Source waters bearing gravel, sand, or silt, or with turbidity in excess of 1,000 NTUs, should have pretreatment. Presedimentation, with or without the addition of a coagulant, is recommended.
- 1. **BASIN DESIGN** – Presedimentation basins should have hopper bottoms or be equipped with continuous mechanical solids removal devices especially selected or designed to remove gravel, sand and/or heavy silt. They should include provisions for rapid draining and hydraulic flushing. Incoming water to non-circular types of basins, e.g., square or rectangular, shall be dispersed across the full width of the line of travel at the inlet end of the basin; short circuiting in all types of basins must be adequately controlled.
 - 2. **CHEMICAL ADDITION** – Provision should be made for adding chlorine and other chemicals for taste and odor control, color removal, and improved removal of turbidity. The formation of DBPs must be considered when selecting treatment chemicals. Also, removal of suspended solids by presedimentation may be enhanced by adding chemical coagulants and rapid mixing. Acrylamide and epichlorohydrin are impurities found in organic polymers used as coagulant aids. Each PWSS must certify annually that the chemicals it uses do not exceed USEPA specified levels of

acrylamide and epichlorohydrin based upon dosage and percentage of the compound in the coagulant aid (KAR 28-15a-111).

3. PRESEDIMENTATION CRITERIA

- a. DETENTION TIME – The recommended minimum detention time is 45 minutes, except for the Kansas and Missouri River sources, for which 2 and 3 hours, respectively, are recommended.
- b. OVERFLOW RATE – The recommended maximum surface overflow rate is 3,500 gpd/ft² (143,000 Lpd/m²); however, higher overflow rates (lower detention times) for basins equipped with inclined plate and/or tube sedimentation equipment may be allowed with prior approval from KDHE.
- c. WATER DEPTH – The recommended minimum side wall depth is 8 ft. (2.4 m).
- d. WEIR RATE – The recommended maximum weir rate is 20,000 gpd/ft (248,000 Lpd/m).
- e. DRAIN LINES – The recommended minimum diameter for drain lines is 8 inches (20.3 cm).
- f. BYPASS – Piping and controls for bypassing a single presedimentation basin shall be provided. Piping and controls for bypassing two or more presedimentation basins in parallel should be provided if appropriate.

F. RAPID MIXING AND COAGULATION – Rapid mixing is the rapid dispersion of coagulation chemical(s) throughout the water being treated, usually by violent agitation. Coagulation is the process of neutralizing the charges on suspended particles and colloids. The design engineer shall identify the basis for rapid mixing and coagulation in terms of the detention time and G values or other appropriate measures of mixing effectiveness for the expected water quantity and quality variations and the chemical(s) to be added. The following items should be among those evaluated when designing a rapid mix system: type(s) and dosages of coagulant(s) to be employed, other chemicals to be fed and the characteristics of each, raw water characteristics, design of chemical diffusers, available head loss, variations in plant flow rate and water temperature, the subsequent solids separation processes, and the quality and quantity of return flows and their potential impacts on coagulation, subsequent treatment processes, and DBP formation.

- 1. REQUIREMENT – Any of several types of mixers can be used to accomplish rapid mixing. These include mechanical mixers, diffusers, injectors, hydraulic mixers, in-line blenders (mechanical and static) and pumps. Baffled mixing chambers are not allowed to serve as the only means of mixing.

2. LOCATION – The rapid mixing and flocculation basins shall be as close together as possible. Typical velocities in conduits from the mixer to flocculation basins are 1.5 to 3.0 ft/s (0.46 to 0.9 m/s). Channels distributing water across the width of a flocculation basin or serving two or more flocculation basins are often tapered, either in width or depth, so as to maintain a constant velocity.
3. RAPID MIX CRITERIA – Inorganic coagulants destabilize colloids by adsorption and charge neutralization or by enmeshment. Polymers function using charge neutralization and/or interparticle bridging mechanisms. The mechanism of colloid destabilization will dictate the chemical dose and the rapid mix design criteria that should be used. Although the velocity gradient (G value) has been widely used as the primary design criterion for evaluating rapid mixers, recent studies have suggested alternate design parameters such as the total power input to the water per unit flow rate (e.g. hp/mgd or hp/cfs ($\text{W/m}^3\text{-d}$ or $\text{W/m}^3\text{-s}$)). Further, for in-line or pump-injection rapid mixing devices, G is difficult to calculate because the volume to be used in the calculation of G is uncertain. Design criteria utilized for a specific rapid mix system should be clearly identified and adequately justified by the design engineer.
4. MECHANICAL MIXERS – METAL SALT COAGULATION (FOR SYSTEMS NOT PRACTICING LIME SOFTENING)
 - a. DETENTION TIME – For conventional treatment plants, the required mixing time should not exceed 30 seconds at the maximum flow rate and should in most cases be less than 10 seconds. The optimal mixing time depends on the mechanism involved and other factors. Metal salt coagulation by adsorption and charge neutralization is thought to be most efficient at detention times less than 1 second, while enmeshment is relatively insensitive to mixing conditions.
 - b. VELOCITY GRADIENT (G VALUE) – For metal salt coagulation, the recommended minimum G value is 500 sec^{-1} . For coagulation using both a metal salt and a polymer, the recommended G value is 600 to 1000 sec^{-1} . Alternatively, the design engineer may submit the design basis which justifies the G value selected, considering the chemicals to be added and water temperature, color and other related water quality parameters.
5. pH CRITERIA – The optimum pH for coagulation depends on water quality and the treatment objectives. For DBP precursor removal, the optimum pH range for metal salt coagulants is typically about 5.5 to 6.0, whereas higher pH values (7.0 to 8.5) are typically optimal for particle removal. Optimum values for the proposed design can be determined by experimentation or from previous experience with the same source of water. Chemicals used to lower the pH should be added before the coagulant, although they can be added together. Chemicals used to raise the pH are typically added as part of the stabilization process; but if they are added during coagulation it

is better to add them after the coagulant, as the coagulant will typically be more effective when hydrolysis occurs at the lower pH.

6. MIXING REQUIREMENTS FOR LIME SOFTENING – When coagulation and lime softening are to occur simultaneously, whether in a process sequence of rapid mixing, flocculation and sedimentation or in a solids contact unit, mixing need not be particularly rapid, but the lime should be completely dissolved. Where rapid mixers are used, a G value of 300 sec^{-1} is typically adequate and a detention time greater than 30 seconds may be desirable to facilitate more complete dissolution of the lime. When solids contact units are used, the lime and coagulant may be added directly into the reaction zone, provided sufficient mixing is available to completely dissolve the lime, or the coagulant may be added ahead of the solids contact unit. The order of addition of lime, coagulant, and other chemicals (e.g., PAC) may significantly influence the properties of the solids, settled-water turbidity, and the removal of trace contaminants (e.g., IOC and SOC). Where full-scale experience is lacking, jar-test or pilot-plant data may be helpful in determining the optimum order of addition.
7. RECYCLE STREAMS – Plants using surface water or GWUI that recycle or have the capability to recycle filter backwash water, thickener supernatant, and liquids from dewatering processes must return these streams to a point in the treatment sequence prior to coagulant or lime addition (KAR 28-15a-76). Depending on the flow rates and solids concentrations involved, solids removal may be necessary to avoid adverse impacts on the effectiveness of coagulation and subsequent treatment processes. Equalization of recycle flows may be necessary to avoid disrupting the coagulation and flocculation processes. A constant recycle flow rate works best.

Recycling of filter wash water for water conservation is usually done using a recovery tank where the supernatant is recycled and the solids are handled separately. Recycling of filter wash water is not recommended where toxic materials or organisms may accumulate in the recycled water.

G. FLOCCULATION – Flocculation is the gentle agitation of water for extended time periods to facilitate the aggregation (or aggregation and growth in the case of lime softening) of smaller particles into larger particles suitable for settling by gravity. It follows rapid mixing for coagulation and is an integral part of both the conventional treatment sequence, as described in the SWTR, and the lime softening process.

1. REQUIREMENT – A mechanical unit is required in all new treatment plants and when existing plants are upgraded.
2. EXCEPTION – A separate mechanical unit will not be required where a solids contact basin with a reaction/mixing compartment is provided.

3. BASIN DESIGN

- a. Inlets and outlets should be designed to minimize floc destruction and short circuiting.
- b. Provision for adjusting mixing energies is required where compartments in series are used. Compartments in series in a single basin are recommended in preference to separate basins in series.
- c. Drains or pumps shall be provided to facilitate rapid dewatering of the unit and removal of accumulated solids.

4. DETENTION TIME – At maximum design flow, a minimum of 20 minutes is required for flocculation (to allow for good floc formation) and 30 minutes for softening (to allow adequate time for the softening reactions to approach equilibrium). Increased time is required where a series of separate flocculation basins is used (as apposed to compartments in series). It is important to note that the extra time will probably help only if it is provided in the last basin, since the primary problem here is floc fragmentation as the water travels between the basins. Detention times should be adjusted for temperature effects (and seasonal changes in flow rate) according to the guidelines in Table V-1.

TABLE V-1
TEMPERATURE ADJUSTMENT GUIDELINES
FOR FLOCCULATOR DETENTION TIME (AWWA AND ASCE, 2005)

Temperature, °C	Detention Time Factor
0	1.35
5	1.25
10	1.15
15	1.07
20	1.00
25	0.95
30	0.90

Many experts believe that flocculators should be designed on the basis of energy input per unit volume, which is not temperature dependent, rather than the G value. The premise for Table V-1 is that one must increase detention time, for a given energy input, in order to maintain the same G value. The values in this table reflect changes in the square root of the viscosity of water. The same result could also be realized by increasing the mixing energy, though this would significantly increase capital and operating costs. While the viscosity of the water is a factor in cold weather performance, many experts in the industry feel that the chemistry is a more important factor in that many cold-weather-related problems can be addressed by raising the pH 0.5 to 1.0 units to account for the temperature-related changes in the solubilities of Fe and Al and the ion product of water, pK_w .

5. EQUIPMENT

- a. Agitators are to be driven by variable speed drives. For vertical, low energy and horizontal, paddle-type flocculators, blade tip speeds in the range of 0.5 to 3.0 ft/sec (0.15 to 0.9 m/s) are appropriate for maximum floc growth and settleability. The tip speed for vertical, high energy flocculators should not exceed 10 ft/sec (3 m/s).
- b. Where three compartments in series are used, G values from 40 to 60 sec^{-1} in the first compartment down to 15 to 25 sec^{-1} in the last compartment are suggested. Higher values are used for softening in order to prevent solids deposition. Vertical, high energy flocculators typically have G values of 50 to 75 sec^{-1} compared to 20 to 45 sec^{-1} for vertical, low energy and horizontal paddle-type flocculators.
- c. External, non-submerged drive equipment is recommended.
- d. A superstructure over the flocculation basins may be appropriate.

6. PIPING

- a. The flocculation and sedimentation basins shall be located as close together as feasible.
- b. The velocity of the flocculated water through pipes, flumes, or effluent ports leading to the settling basin should not exceed 1.5 ft/sec (0.46 m/s) to avoid floc shear and should not be less than 0.5 ft/sec (0.15 m/s) to prevent settling before entering the basin. Most flocculators have an end baffle between the flocculation zone and the clarifier to prevent residual energy of the flocculation process from being transferred to the clarification stage.
- c. Allowances must also be made to minimize turbulence at bends and changes in direction.

H. SEDIMENTATION – Sedimentation shall follow flocculation except where dissolved air flotation (Section I) or direct filtration (Section J) has been approved.

1. GENERAL REQUIREMENTS – The requirements for effective clarification depend on basin design and raw water quality (turbidity, color, colloidal matter, taste and odor causing substances, or other material to be removed). The character of the floc formed is a major consideration. Sound engineering judgment is required to produce a good cost-effective design.
 - a. **BASIN DESIGN** – Conventional or solids contact units may be used. Conventional units can be circular, square, or rectangular. Solids contact basins are upflow units that utilize a zone where previously formed and settling floc interacts with incoming particles.
 - b. **INCLINED SETTLERS** – Plate or tube settlers may be used and a reduction in detention time is allowed with their use.
 - c. **DETENTION TIME** – Calculations for detention time requirements should be based on the maximum design flow.
 - d. **INLETS** – Inlets for square or rectangular shaped horizontal flow units should be designed to distribute the flow uniformly across the cross section of the basin. Balanced energy inlets, biased gates, baffle walls or similar entrance arrangements are recommended. A baffle should be constructed across the basin close to the inlet end or between the flocculation and sedimentation basins to dissipate inlet currents and provide uniform flow across the basin. Baffle walls are more effective than target baffles. Circular basins may have a center feed with radial flow, or a peripheral (rim) feed with radial flow. Regardless of the basin geometry, the design should provide a proper flow pattern with minimal floc breakup.
 - e. **OUTLET AND OVERFLOW DEVICES** – Means for controlling the maximum water level in the filters and basins shall be provided. Outlets, when used, should be designed to maintain velocities suitable for settling in the basin and to minimize short circuiting. Weirs or submerged orifices can be used on effluent troughs to minimize short circuiting; but submerged orifices should not be located more than three feet below the water line. An overflow weir installed to establish the maximum water level on top of the filters shall discharge by gravity, with a free fall, at a location where the discharge will be seen.

Weirs should be easily accessible for cleaning and maintenance. Each trough section should have sufficient drain holes in the bottom to relieve loadings when the basin is drained or filled. When lime softening is practiced,

overflow weirs and troughs will tend to become encrusted with CaCO_3 . Using troughs with submerged orifices may lessen this problem.

- f. DRAINAGE – Basins should be provided with the means for rapid dewatering. Basin bottoms should slope toward the drain. Drainage facilities shall not be physically connected to the sanitary sewer system except where proper cross-connection protection is provided such as an air-gap separation between the basin and the sanitary sewer connection.
- g. SOLIDS COLLECTION – Mechanical solids collection equipment shall be provided. Rakes and drive units should be designed to restart at the expected solids concentration after a 24-hour shutdown (especially in solids contact basins used for softening), and provision should be made for reversing the motor to assist in freeing the rake after shutdown.
- h. SOLIDS REMOVAL
 - 1) Solids withdrawal pipes shall be not less than 4 inches (10.2 cm) in diameter for clarification and not less than 6 inches (15.2 cm) in diameter for softening with the designer having the latitude to select larger diameter withdrawal pipes as deemed appropriate for the design to facilitate routine flushing and cleaning.
 - 2) Entrances to solids withdrawal pipes shall be designed to prevent clogging.
 - 3) Valves shall be located outside the tank for accessibility.
 - 4) The operator shall be able to observe and sample solids being withdrawn from the unit.
- i. SOLIDS DISPOSAL – Facilities are required for the proper disposal of solids.
- j. CROSS CONNECTIONS
 - 1) Solids blow-down outlets and solids withdrawal lines and drains must be designed to prevent backsiphonage.
 - 2) Cross-connection control must be included when potable water is used to back-flush solids withdrawal lines.

2. CONVENTIONAL BASIN CRITERIA

a. MINIMUM DETENTION TIMES

- 1) When no inclined settlers are used:
 - a) Kansas, Missouri, and Neosho Rivers:
 - (1) With presedimentation – 3 hours.
 - (2) Without presedimentation – 4 hours.
 - b) All other surface supplies – 3 hours.
 - c) Precipitative softening facilities treating only groundwater sources – 2 hours.
- 2) When inclined settlers are used:
 - a) Missouri and Kansas Rivers – designer must justify reduced detention times.
 - b) Neosho River – 2 hours.
 - c) Others – 1.5 hours.

b. OVERFLOW RATE

- 1) The recommended maximum surface overflow rate for horizontal flow basins is 600 gpd/ft² (24,400 Lpd/m²).
- 2) When effluent weirs are used in lieu of a ported outlet wall, the rate of flow over the outlet weir should not exceed 20,000 gpd/ft (248,000 Lpd/m) of weir length for horizontal flow basins. The surface overflow rate should not exceed 2,160 gpd/ft² (88,000 Lpd/m²) for the surface area covered by the trough system. Weir coverage should extend one-third to preferably one-half from the end of the basin toward the inlet end. The performance of circular basins greater than 50 to 60 ft. (15 to 18 m) in diameter may be improved by the use of inboard circumferential effluent troughs. A double-sided weir trough mounted inboard at least 15 percent of the tank radius is recommended.
- 3) Submerged exit ports used as an alternative for overflow weirs should be located no more than 3.0 ft. (0.9 m) below the water line at

maximum flow with loading rates equivalent to the weir loading rate in Subsection H.2.b.2 above.

c. **BASIN DIMENSIONS**

- 1) Minimum depth – 8 ft. (2.4 m).
- 2) The minimum length to width ratio for rectangular settling basins shall be 2.5:1. Ratios of 4:1 or more are recommended.

d. **INCLINED SETTLERS** – Where existing basins are adequate structurally and hydraulically, their capacities may be increased by installing approved inclined settlers (tubes or plates) provided that the new detention time is not less than the standards listed above and the following criteria are met:

- 1) Application Rate – A maximum rate of 2,880 gpd/ft² (117,000 Lpd/m²) for tube or plate settlers based on 2 foot (0.6 m) long 60° tubes or 39.6 inches (101 cm) long 7.5° tubes. Higher rates are not permitted unless successfully shown to be appropriate through pilot or in-plant demonstration studies.
- 2) Protection from Freezing – Outdoor installations must provide sufficient freeboard above the top of the settlers to prevent freezing in the units. A cover or enclosure is strongly recommended.
- 3) Drainage – Drain piping from the settler units must be sized to facilitate a quick flush without flooding other portions of the plant.
- 4) Flushing Lines – Flushing lines shall be provided to facilitate maintenance and must be protected against backflow and backsiphonage.

3. **SOLIDS CONTACT BASIN CRITERIA** – Solids contact units are acceptable for clarification or precipitative softening where water characteristics are not highly variable and flow rates are reasonably uniform.

- a. **INSTALLATION AND START-UP OF EQUIPMENT** – A manufacturer's representative should supervise the installation and initial operation of all mechanical equipment.
- b. **OPERATION OF THE EQUIPMENT** – The following should be provided by the manufacturer for routine plant operation of mechanical units.
 - 1) A complete set of tools and accessories.

- 2) Identification of process control procedures and suggested test equipment.
 - 3) Sampling taps located so as to permit the collection of samples which will allow process control and monitoring requirements to be satisfied.
- c. CHEMICAL FEED – Chemicals should be applied at such points and by such means as to ensure their satisfactory mixing with the water that is treated. (Also see Chapter IX on Chemical Storage, Handling, and Application.)
- d. MIXING
- 1) Mixing devices should be so constructed that the raw water or partially treated water is thoroughly mixed with the previously formed suspended particles.
 - 2) The mixing blade tip speed should generally not exceed 10 ft/sec (3 m/s) to avoid shearing the floc, but the mixer speed must be fast enough to prevent deposition of solids in the mixing zone.
 - 3) Mixers shall be adjustable for variable speed and be able to produce G values of 20 to 70 sec⁻¹.
 - 4) Softening units should be capable of maintaining solids concentrations in the mixing/reaction zone of at least one percent by weight (or about 5% by volume depending on settling time and specific gravity).
 - 5) A recirculation ratio of 10 to 1 at design flow is recommended. The mixing device should be able to thoroughly mix the recirculated stream with the primary stream at maximum plant flow.
- e. MIXING VOLUME – The volume of the mixing compartment is measured to the bottom of the skirt (mixing zone wall).
- f. DETENTION TIME – The detention time shall be established on the basis of the raw water characteristics and other local conditions that affect the operation of the unit. Based on the maximum design flow rate, the detention time should be:
- 1) Two to four hours for solids contact clarifiers and softeners treating surface water.

- 2) One to two hours for solids contact softeners treating only groundwater.
 - 3) The flocculation and mixing zone detention time shall be not less than 30 minutes nor greater than 40 minutes at maximum design flow for clarification and not less than 20 minutes for softening units. A minimum detention time of 15 minutes will be considered for softening units where adequate justification is provided.
- g. OVERFLOW RATES – Unless supporting data are submitted to KDHE to justify alternative values, the following overflow rates are required:
- 1) The overflow rate for clarification units shall not exceed 1.0 gpm/ft² (41 L/min-m²) at the solids separation line.
 - 2) The overflow rate for softening units shall not exceed 1.75 gpm/ft² (71 L/min-m²) at the slurry separation line.
- h. SOLIDS CONCENTRATORS
- 1) Either internal or external solids concentrators shall be provided to permit solids concentration and to minimize water loss.
 - 2) Large units should have at least two solids-collecting sumps, located below the central flocculation/reaction zone.
 - 3) Solids must be able to be drawn off frequently and for short durations, such that the desired slurry concentration can be readily maintained.
- i. WATER LOSSES
- 1) Units shall be provided with suitable controls for solids withdrawal.
 - 2) Total water losses should not exceed:
 - a) Five percent for clarifiers.
 - b) Three percent for softeners.
- j. OUTLETS
- 1) Solids contact units may be equipped with troughs employing overflow weirs or submerged orifices. Water at the surface of the

unit must not travel horizontally over 10 ft. (3.0 m) to a collection trough.

- 2) The maximum weir loading rate is 10 gpm/ft (14,400 gpd/ft, 125 L/min-m or 180,000 L/d-m) for clarification and 20 gpm/ft (28,800 gpd/ft, 250 L/min-m or 360,000 L/d-m) for softening.
- 3) Weirs shall be adjustable, at least equivalent in length to the perimeter of the tank if the tank is circular, and constructed so that they will produce a uniform rise rate over the entire area of the tank. When submerged orifices are used the loading rates per foot of launder should be no greater than the maximum allowable weir loading rates.
- 4) Other high-rate clarification processes may be approved if it is satisfactorily demonstrated to KDHE, by means of on-site pilot or full-scale demonstrations involving the same or similar water quality conditions, that they perform well and meet all applicable regulatory requirements. Reductions in detention times, increases in overflow rates and weir loading rates, and other exceptions to the relevant portions of Subsections 1 through 3 above shall be adequately justified. Examples of such processes include floc-blanket clarification (with or without pulsing), ballasted flocculation, contact flocculation, contact clarification, and helical-flow solids contact clarifiers. Subsection A.5 of Chapter III (New Processes, Methods, Chemicals and Equipment) may also be pertinent.

- I. **DISSOLVED AIR FLOTATION** – Dissolved air flotation has found limited application in the clarification of waters typical of those found in Kansas. It is best suited for treating waters for which coagulation produces a light, slowly settling floc, e.g., those laden primarily with algae or organic matter (color) rather than turbidity. Design of DAF units must be based on pilot or in-plant demonstration studies approved by KDHE. Typical DAF units are rectangular with a depth of 10 ft. (3 m), a surface overflow rate in the range of 4 to 5 gpm/ft² (163 to 204 L/min-m²) and a nominal detention time in the flotation tank of between 5 and 15 minutes.
- J. **FILTRATION** – Rapid rate gravity sand filters are recommended for all PWSSs treating surface water or GWUI. Rapid rate refers to the hydraulic loading on the filter. Filtration technologies other than rapid-rate gravity sand filtration are subject to approval by KDHE and proposals to employ them should be discussed with KDHE prior to submittal of a permit application. Filters used for PWSSs must be designed to meet the filtration requirements specified in KAR 28-15a-73, as well as those specified in KAR 28-15a-173 and 174 (if serving 10,000 or more people) or KAR 28-15a-550 through 553 and KAR 28-15a-560 through 562 (if serving fewer than 10,000 people). PWSSs using surface water or GWUI as

a source of supply must also comply with the provisions of KAR 28-15a-76, which regulates recycle flows, including filter backwash water.

GAC filter-adsorbers may be used for taste and odor control and may in some cases be appropriate for the removal of SOC. Typical GAC bed lives are one to five years for taste and odor control, but laboratory and/or pilot-plant studies are recommended to confirm GAC requirements, especially for SOC removal, since naturally occurring organic matter can greatly reduce adsorptive capacity. GAC may be used in post-filter adsorbers (Section Q), as a replacement or topping medium in existing filters, or in new filter-adsorbers. See Subsection 5.b.4 for design requirements pertaining to GAC filter-adsorbers.

Pressure filters for treating groundwater or GWUI will be considered for approval on a case-by-case basis. Pressure filters have two significant disadvantages: an increased likelihood that particles (perhaps including pathogens) will be dislodged by hydraulic surges, and designs that interfere with the ability of the operator to observe the filter during filtration and backwashing and to physically inspect the media. For these reasons, gravity filters are preferred for PWSSs. See Subsection 13 for design requirements pertaining to pressure filters.

Bag or cartridge filter systems may be approved for treatment of groundwater or GWUI, but for GWUI the effectiveness of the proposed system for removal of *Giardia lamblia* and *Cryptosporidium* cysts and for complying with turbidity requirements must be established as required by KAR 28-15a-73. Appendix M of the USEPA's *Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources* (USEPA, 1991) presents various approaches that can be utilized to demonstrate the effectiveness of alternate filtration technologies such as bag or cartridge systems. A bag or cartridge system physically removes particles by trapping them on specially designed material such as microporous ceramic elements or polypropylene woven fabrics. The bag or cartridge is installed in a cylindrical housing unit (canister) and is removed from the housing unit and replaced when buildup of particulate matter results in excessive pressure drop across the unit. Engineering considerations include evaluating the necessity for pretreatment, pumping requirements, and the number, size, and arrangement of filter units necessary to treat a particular source. See Subsection 14 for additional design requirements pertaining to bag and cartridge filtration systems.

The design criteria presented in Subsections 1 through 12 below apply specifically to rapid rate gravity filters, but many of them are also applicable to other types of filters. Design criteria pertaining specifically to pressure filters, bag and canister filters, and biofiltration are presented in Subsections 13, 14, and 15, respectively. Design criteria for GAC filter-adsorbers are presented in Subsection 5.b.4 and in Section Q. Design criteria for deep-bed mono-media filters are presented in Subsection 5.b.5. Design criteria for membrane processes, including microfiltration and ultrafiltration, which are increasingly being considered as alternatives to rapid rate gravity filtration, are presented in Section S (Membrane Processes). Design criteria for slow sand filtration, diatomaceous earth filtration, and direct filtration are not presented herein, since these filtration technologies are typically

not employed in Kansas. Proposals to employ these technologies, or any filtration technology other than rapid rate gravity filtration, should be discussed with KDHE prior to submittal of a permit application.

1. PRETREATMENT AND NUMBER

- a. PRETREATMENT – Pretreatment is required ahead of all rapid rate gravity filters.
- b. NUMBER – At least two units shall be provided. Where only two units are provided, each shall be capable of meeting the maximum design flow at the approved filtration rate. Where more than two filters are provided, the filters shall be capable of meeting the maximum design flow with one filter removed from service. Where declining rate filtration is provided, the variable nature of the filtration rates must be considered when determining the number of filters required.

2. STRUCTURAL AND HYDRAULIC DETAILS

- a. FILTER BOX DEPTH – The minimum depth of the filter box shall be 10 ft. (3.0 m).
- b. MINIMUM WATER DEPTH – The minimum water depth over the surface of the media shall be 3 ft. (0.9 m).
- c. MAXIMUM WATER VELOCITY – The maximum velocity of the water in the pipes and conduits leading to the filters shall be 2 ft/sec (0.6 m/s).
- d. WALKWAYS – Walkways around the filters shall be not less than 2 ft. (0.6 m) wide and not more than 3.5 ft. (1.1 m) below the top of prefabricated filters. An access walkway is required for prefabricated filters so that filter operation, especially backwashing, can be easily observed.
- e. OTHER CONSIDERATIONS – The filter system should be designed with the following structural and hydraulic features:
 - 1) Vertical walls within the filter with no protrusion of the filter walls into the filter media;
 - 2) Cover by a superstructure with roof drains that shall not discharge into the filters or any basin preceding or following the filters;
 - 3) Head room to permit normal inspection and operation;
 - 4) Trapped effluent to prevent backflow of air to the bottom of filters;

- 5) Curbs at least 4 inches (10.2 cm) high around the filters to prevent drainage into the filters;
 - 6) Prevention of flooding by providing an appropriately sized overflow;
 - 7) Cleanouts and straight alignments for influent pipes or conduits where solids loading is heavy, or following precipitative softening;
 - 8) A washwater drain with capacity to carry maximum flow;
 - 9) Backwash piping located below the media;
 - 10) Safety handrails between the filter and the walkways even if one or more filters are walled from the general gallery aisle;
 - 11) Materials contacted by wetted GAC to be resistant to corrosion and abrasion;
 - 12) Inlet design with provisions to mitigate turbulence and noise due to falling water where elevation of filter inlet is higher than the elevation of the water level in the filter box; and
 - 13) Prevention of cross-connections and common walls between filtered and unfiltered water, including on-site sources of groundwater, and between potable and non-potable water. A dry well to separate filters from prior treatment steps will be required when there would otherwise be only a common wall between them.
- f. APPURTENANCES – The following items should be provided (shall be provided, where regulatory requirements are referenced) with every filter:
- 1) Provisions to sample the influent and effluent streams;
 - 2) Provisions to measure head loss across the filter;
 - 3) Indicating and recording flow rate controller;
 - 4) Provisions to drain the filters to waste when treating surface water or GWUI, with appropriate measures to prevent backflow;
 - 5) Effluent turbidimeter for the combined filter effluent and, if treating surface water or GWUI at a treatment facility serving more than 10,000 people (KAR 28-15a-174) or serving fewer than 10,000 people and using conventional filtration (KAR 28-15a-560) or having more than two filters, an individual filter effluent turbidimeter for

each filter, capable of meeting the analytical requirements described in KAR 28-15a-74 and recording the effluent turbidity reading at least once every 15 minutes;

- 6) An alarm connected to the turbidimeter to signal unacceptable turbidity levels in the water being delivered to the distribution system with an option to shut down the service pumps; and
 - 7) A properly sized pressure hose (with storage rack) that will provide an adequate quantity of water at the pressure needed to wash filter walls.
3. FLOW CONTROL – Any of several different kinds of flow control systems can be employed. Designers should identify and validate the basis for their choice of control system.
4. UNDERDRAINS – Block or false bottom underdrain systems, with or without gravel, are acceptable. Porous plate underdrains are not recommended due to their potential to clog over an extended period of time, especially where precipitation or deposition of aluminum, iron, manganese, silica, calcium, phosphate, organic matter (including polymers used for treatment), or other substances may occur. Changes in chemical feed or water quality must be taken into consideration in evaluating them for use even if they are “compatible” with a given water under one set of operating conditions. Underdrain design should minimize loss of head while ensuring an even distribution of washwater and an even rate of filtration over the entire area of the filter. The maximum underdrain loading rate for the collection of filtered water and the uniform distribution of backwash water shall not be less than 20 gpm/ft² (814 L/min-m²) of filter surface area.
5. FILTER MEDIA
 - a. QUALITY – Media quality shall conform to applicable AWWA standards for filtering material (i.e., B100 for granular media and supporting gravel and B604 for GAC).
 - b. CRITERIA FOR COMMON BED TYPES
 - 1) Single Media Beds – Silica sand is the approved filter material. Anthracite coal will be considered for approval only under special conditions.
 - a) For rapid sand filters, the minimum depth is 27 inches (0.7 m) for sand and 42 inches (1.1 m) for anthracite coal.

- b) For rapid rate filters, the sand or anthracite coal shall have an effective size of 0.45 to 0.55 mm with a uniformity coefficient of 1.65 or less.
- 2) Dual Media Beds – Coal-sand filters shall consist of a coarse anthracite coal layer above a layer of fine sand. Some mixing of coal and sand at their interface is acceptable.
- a) The minimum total depth of filter media should be at least 30 inches (76 cm).
 - b) The coal layer should be at least 18 inches (46 cm) thick.
 - c) The fine sand layer should be 12 inches (30.5 cm) minimum thickness. If 3 inches (7.6 cm) of fine gravel support media having an effective size of 0.8 to 2 mm and a uniformity coefficient no greater than 1.7 is used, a 9 inch (22.9 cm) minimum thickness of fine sand will be approved.
 - d) The sand and coal effective sizes shall be 0.4 to 0.55 mm and 0.8 to 1.1 mm with uniformity coefficients no greater than 1.65 and 1.7, respectively. The effective size of anthracite coal when used as a cap shall be 0.8 to 1.2 mm with a uniformity coefficient of 1.85 or less.
- 3) Mixed Media Beds – Filter beds of this type typically contain a layer of anthracite coal, a layer of silica sand, and a layer of garnet sand or ilmenite. After backwashing with water, the relative size and density of the particles will result in a filter bed with filter media and pore spaces graded progressively from coarse to fine in the downward direction of filtration.

A typical 30 inch (76 cm) bed consists of 16.5 inches (41.9 cm) of anthracite coal, 9 inches (22.9 cm) of silica sand, and 4.5 inches (11.4 cm) of garnet or ilmenite sand. Typical effective sizes are 0.8 to 1.1 mm, 0.35 to 0.5 mm, and 0.15 to 0.35 mm for the coal, sand, and garnet, respectively. Use of other bed depths and media distributions must be approved by KDHE.

- 4) GAC Filter Adsorbers – A GAC filter-adsorber can be made by replacing a medium in an existing filter with GAC, by capping an existing filter, or by constructing a new filter-adsorber. The sand can be replaced in a single media filter or the coal in a dual or mixed media filter. Additional information pertaining to GAC contactors and their design can be found in Subsection Q, Adsorption with GAC.

A 30 inch (76 cm) layer of 12 x 40 mesh GAC (effective size of 0.55 to 0.65 mm) is typically employed when replacing the coal or anthracite in a single-media filter; and a 12 to 18 inch (30.5 to 46 cm) layer of 8 x 30 mesh GAC (effective size of 0.80 to 1.0 mm) is typically employed for capping or to replace the coal in a dual or mixed media bed.

A filter adsorber must meet all applicable filter performance and design criteria. The GAC used must be compatible with the filtration and backwashing systems employed; and, when two or more filter media are used, care must be taken to be sure that they fluidize and restratify properly, relative to one another, during backwash.

Since bacteria can grow on and slough off from GAC, and since GAC reacts with chlorine, provision must be made for a post-GAC free chlorine residual and adequate contact time to prevent the growth of nuisance organisms or opportunistic pathogens in subsequent portions of the treatment sequence and the distribution system. Provision must also be made for periodic treatment of the filter media to control bacterial and other growths and for replacement or regeneration of the GAC.

- 5) Deep Beds – Rapid rate gravity filters with media depths equal to or greater than 48 inches (1.2 m) are referred to as “deep-bed” filters. Both mono-media and dual-media designs are employed, with a larger grain size being used to reduce head loss and a deeper bed being used to give the contaminant particles approximately the same opportunity to be removed as in a conventional filter. Careful attention shall be paid to the design of the backwash system, which usually includes simultaneous air scour and water backwash at subfluidization velocities.

Deep bed filters may be considered based on pilot studies pre-approved by KDHE. The final filter design shall be based on the pilot studies and shall comply with all applicable portions of Subsections 1 through 12 and 15.

c. FILTER MEDIA PLACEMENT

- 1) Prior to the placement of filter material, the filter basin shall be cleaned thoroughly by means of a high-pressure water jet, scrubbing, or equally effective means. The filter media shall be placed in the filter basin, backwashed and prepared for service in accordance with AWWA Standard B100. After all work related to placement of media has been completed, and before the filter is placed into service,

the entire filter shall be disinfected in accordance with AWWA Standard C653. Special disinfection procedures apply to GAC, since it reacts with chlorine. These procedures are described in AWWA Standard B604.

- 2) When a medium is first installed, as many as ten backwashes may be necessary before the filter effluent is void of media fines.

6. UNDERDRAINS AND SUPPORT GRAVEL – Many filters use underdrain systems with graded gravel layers to support the media and to prevent its entry into the underdrain openings. The following guidelines should be followed to establish the gradations of the adjacent layers:

- a. Each gravel layer should be as uniform as possible, preferably retained between sieve openings that differ by a factor of two or less.
- b. The bottom-layer fine size should be 2 to 3 times the orifice diameter of the underdrain system.
- c. The top-layer fine size should be 2 to 4.5 times the effective size of the media to be retained.
- d. From layer to layer, the fine size of the coarser layer should be less than or equal to 2 times the fine size of the adjacent finer layer.
- e. Each layer should be at least 2 inches (5.1 cm) thick or 3 times the coarse size of the layer, whichever is greater.

7. RATE OF FILTRATION – The rate of filtration shall be determined through consideration of such factors as raw water quality, degree of pretreatment, filter media, water quality control parameters, competency of operating personnel, and other factors as required by KDHE.

- a. NEW FILTER SYSTEMS – The following filtration rates are approved for new treatment plants that clarify, soften or remove hydrogen sulfide, iron and manganese, taste and odor, or trace organics:

Single Media	3.0 gpm/ft ² (122 L/min-m ²)
Dual Media	4.0 gpm/ft ² (163 L/min-m ²)
Mixed Media	5.0 gpm/ft ² (204 L/min-m ²)

- b. EXISTING FILTER SYSTEMS – For existing filter systems, the above listed filtration rates may be used provided the following conditions are met:

- 1) Pre-filtration treatment facilities meet applicable KDHE requirements;
 - 2) The filter system including support media, underdrain, and hydraulic controls is in satisfactory condition and meets applicable KDHE requirements; and
 - 3) KDHE approval to increase beyond the previously permitted rates of filtration is obtained.
- c. **HIGHER FILTRATION RATES** – Higher filtration rates will be considered for approval, if justified by the design engineer and shown to be satisfactory to KDHE by pilot or in-plant testing.
 - d. **POLYMER USAGE** – Polymeric filter aids are typically helpful or necessary for meeting today's more stringent turbidity limits, especially at higher filtration rates. Thus, the use of polymeric filter aids should be evaluated for all rapid-rate filters.
8. **BACKWASH** – Provisions should be made for backwashing, including:
- a. Filtered water provided at the required rate by washwater storage (tanks and/or clearwells), washwater pumps, from the high service main, or a combination of these. Use of water from high pressure mains is not recommended except for standby service; but this alternative may be approved under special conditions. Duplicate washwater pumps are required unless an alternate means of obtaining water is available.
 - b. A washwater regulator or valve on the main washwater line at a minimum to obtain the desired filter backwash water flow rate when the valve on any one individual filter is wide open. The system design shall include provisions to prevent rapid changes in backwash water flow.
 - c. A rate-of-flow indicator, preferably with a totalizer, on an operator console that is located so that the backwash water flow rate can be easily read by the operator during the backwashing process. In small plants, where an operator console is not used, a flow gauge must be installed in the washwater line.
 - d. Means to prevent accumulation of air in the filter washwater supply piping and pump between backwashes.
 - e. Provisions for filtering to waste with appropriate measures for backflow prevention.

- f. Proper disposal of the backwash water and/or its supernatant, in compliance with KAR 28-15a-76.

9. BACKWASH RATE AND DURATION

- a. The minimum rate of flow for filter backwashing without air scouring shall be 15 gpm/ft² (611 L/min-m²); however, a minimum rate of 20 gpm/ft² (814 L/min-m²) is recommended. These rates correspond to water temperatures of 68°F (20°C) and 86°F (30°C), respectively. A reduced rate may be acceptable for full depth, single-media anthracite or GAC filters.

Water temperature must be taken into account when selecting the minimum rate of flow as each degree Celsius increase in temperature requires roughly a 2 percent increase in the backwash flow rate to maintain the same degree of bed expansion.

- b. The minimum duration of a filter backwash without air scour, for design purposes, is 15 minutes at the design rate of flow.
- c. Requirements for backwash water storage tanks are described in Chapter VI, Subsection A.5.a.

10. BACKWASH EQUIPMENT

- a. Filter bottoms shall be designed to distribute the washwater evenly over the entire filter area and to withstand all imposed hydraulic and structural stresses.
- b. The bottoms of the washwater troughs should be above the maximum level of the expanded media during backwashing.
- c. The top edge of each washwater trough should be level, and all the troughs should be at the same elevation.
- d. Washwater troughs should be spaced so that each serves an equal amount of filter surface area. The maximum horizontal travel of suspended solids to reach a washwater trough shall not exceed 3 ft. (0.9 m).
- e. Washwater troughs should have a 2 inch (5.1 cm) freeboard at the maximum backwash rate.

11. SURFACE WASH OR SUBSURFACE WASH – Surface or subsurface wash facilities are required except for filters used exclusively for iron and manganese removal. Air scouring may be approved in place of surface wash based on experimental data and operational experience. A surface wash system of fixed

nozzles or, preferably, nozzles affixed to revolving arms may be used to apply the washwater to the media surface. All surface wash devices should be designed with:

- a. Provision of a water pressure of at least 55 psi (380 kPa).
- b. A vacuum breaker or other acceptable device installed at least 1 foot (0.3 m) above high water level in the filter or other device to prevent backsiphonage.
- c. Spacing of 2 to 3 ft. (0.6 to 0.9 m) for fixed nozzles and 4 to 8 inches (10.2 to 20.3 cm) for those on revolving arms, with the nozzle orifices about 2 inches (5.1 cm) above the unexpanded media.
- d. Rate of flow of 2.0 to 4.0 gpm (7.6 to 15.1 L/min) and 0.5 to 1.0 gpm (1.9 to 3.8 L/min) per square foot of filter area for fixed and revolving arms, respectively.

12. AIR SCOURING – Air scouring can be used in place of surface wash.

- a. Air flow and concurrent washwater rates must be matched to fit the media type and size used. Typical air flow is 3 to 5 scfm/ft² (0.9 to 1.5 m³/min-m²) when the air is introduced in the underdrain; a lower air rate must be used when the air scour distribution system is placed above the underdrains. Generally, concurrent backwash water rates are in the range of 4 to 7 gpm/ft² (163 to 285 L/min-m²).
- b. The backwash system must be capable of delivering washwater at a minimum rate of 15 gpm/ft² (611 L/min-m²); however, when air scour is provided the washwater rate must be variable and should not exceed 8 gpm/ft² (326 L/min-m²), unless operating experience shows that a higher washwater rate is necessary to remove particles scoured from the surfaces of the filter media.
- c. Air scouring can be followed by a fluidization wash sufficient to restratify the media if this is desirable.
- d. A method for avoiding excessive loss of filter media during backwashing must be provided. Some systems are equipped with a baffle arrangement; other systems use a lower washwater flow rate during periods of concurrent air flow.
- e. Air must be free of contamination, e.g., dirt, dust, fumes, oil, etc.
- f. Air scour system designs for new filters shall directly deliver air to underdrains designed to evenly distribute the air. When air distribution piping is required, the piping shall be sufficiently strong and rigid, shall not

be subject to erosion at orifice openings due to the passage of air at high velocities, and shall be securely anchored and supported.

- g. Consideration shall first be given to designs that deliver air directly to the underdrain at or below the support/filter media interface when retrofitting existing filters for air scour.
- h. Where existing filter underdrains are inaccessible, KDHE will consider, on a case-by-case basis, designs that locate air scour systems in filter boxes, according to the following:
 - 1) Air scour distribution systems shall introduce air at an elevation no greater than that of the interface between the filter media and the support media or underdrain;
 - 2) Designs for placement at the interface shall prevent media from clogging orifices and diffusers, and from entering the air scour distribution system;
 - 3) Air scour piping shall be constructed of stainless steel, be of sufficient strength and rigidity to withstand the operational cycles of a filter, support the filter load without collapse, and not be subject to erosion at orifice openings;
 - 4) Anchoring and support systems shall be constructed of the same material as the piping; and
 - 5) The full depth of filter media shall be determined as measured from the elevation of the top of the air scour system.
- i. KDHE will on a case-by-case basis consider designs where air delivery piping must out of necessity pass downward through the filter media, according to the following:
 - 1) Drop pipes shall be constructed of the same type of stainless steel material used for air scour piping, anchors and supports;
 - 2) Drop pipes shall be single, jointless lengths of seamless stainless steel pipe with a wall thickness that precludes short circuiting resulting from failures such as breaks, cracks and/or corrosion;
 - 3) Drop pipe/lateral tee connections shall be factory welded and pressure tested; and
 - 4) Drop pipes may not pass through backwash water troughs.

- j. Consideration shall be given to maintenance and potential replacement of the air scour system piping and related appurtenances.
 - k. Neither the air scour system design nor the filter design shall allow for a cross-connection between the applied unfiltered water and the filtered water.
13. RAPID RATE PRESSURE FILTERS – The normal use of these filters is for iron and manganese removal. Pressure filters shall not be used in the filtration of surface water (including GWUD) or following lime-soda ash softening.
- a. GENERAL – Minimum criteria relative in part to rate of filtration, structural details, hydraulics and filter media provided for rapid rate gravity filters also apply to pressure filters where appropriate.
 - b. RATE OF FILTRATION – The rate shall not exceed 4 gpm/ft² (163 L/min-m²) of filter area except where in-plant testing as approved by KDHE has demonstrated satisfactory results at higher rates.
 - c. DETAILS OF DESIGN – The filters shall be designed to provide:
 - 1) Loss of head gauges on the inlet and outlet pipes of each battery of filters;
 - 2) An easily readable meter or flow indicator on each battery of filters, preferably a flow indicator on each filter;
 - 3) The ability to operate each filter individually, in either a filtration or backwashing mode, with a piping arrangement as simple as possible to accomplish these purposes;
 - 4) A minimum side wall shell height of five feet, except where a corresponding reduction in side wall height is acceptable to KDHE based on use of a proprietary underdrain that permits reduction of the gravel depth;
 - 5) At least 18 inches (46 cm) between the top edge of the backwash water collectors and the surface of the media;
 - 6) An underdrain system to efficiently collect the filtered water and to uniformly distribute the backwash water at a rate not less than 15 gpm/ft² (611 L/min-m²) of filter area;
 - 7) Backwash flow indicators and controls that are easily readable while operating the control valves;

- 8) An air release valve on the highest point of each filter;
- 9) Manholes, at least 24 inches (61 cm) in diameter where feasible, to facilitate inspection and repairs of filters 36 inches (91 cm) or more in diameter, and sufficient handholds for filters less than 36 inches (91 cm) in diameter;
- 10) Means for the operator to directly (visually) observe the wastewater produced during backwashing; and
- 11) Construction that prevents cross connections.

14. BAG AND CARTRIDGE FILTERS – Proposals to use bag or cartridge filters should be discussed with KDHE prior to submittal of a permit application. Such proposals will be evaluated based on site-specific and other considerations, including the following:

- a. The filter housing and bag/cartridge filter must demonstrate a filter efficiency of at least 2-log reduction in particles 1 micron in size or larger. Demonstration of higher log removals may be required by KDHE depending on raw water quality and other treatment steps to be employed. Bag or cartridge filters used for compliance with 40 CFR 141.700 et seq. (LT2ESWTR) must meet the definition of bag or cartridge filtration (40 CFR 141.2) and their removal efficiency must be established as described in 40 CFR 141.719(a).
- b. For applications involving GWUI, the necessary log reductions of *Giardia lamblia* and *Cryptosporidium* cysts and for complying with the turbidity requirements established by KAR 28-15a-73 must be demonstrated using procedures acceptable to KDHE. Acceptable procedures include: evaluation of *Giardia* and *Cryptosporidium* surrogate particles in accordance with NSF International's ANSI/NSF Standard 53 or equivalent (conducted by NSF International or by another third party acceptable to KDHE); and the "Particle Size Analysis Demonstration for Giardia Cyst Removal Credit" procedure in Appendix M of USEPA's *Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources* (USEPA, 1991).
- c. The demonstration of filter efficiency is applicable only to a specific housing used in combination with a specific bag or cartridge filter. Any other combinations of different bags, cartridges, or housings will require additional demonstration of filter efficiency.
- d. KDHE will decide whether or not a pilot demonstration is necessary for each installation.

- e. System components such as housing, bags, cartridges, membranes, gaskets, and O-rings should be evaluated under NSF International's ANSI/NSF Standard 61 or equivalent, for leaching of contaminants.
- f. The source water or pretreated water turbidity should be less than 5 NTU.
- g. The flow rate through the treatment process shall be monitored with a flow valve and meter. The flow rate through the bag/cartridge filter must not exceed the maximum flow rate at which the applicable removal efficiencies were demonstrated.
- h. Pretreatment using pressure filters or bag or cartridge filters with larger openings is recommended when it will provide more constant water quality to the bag/cartridge filter and will extend bag or cartridge life.
- i. A filter to waste component is strongly recommended for pressure filters used for pretreatment. At the beginning of each filter cycle and/or after every backwash of the pre-filters, a set amount of water should be discharged to waste before water flows into the bag/cartridge filter. Filter to waste shall be provided for the final filter(s) and a set amount of water shall be discharged to waste after changing the filters.
- j. If pressure filters are used for pretreatment they must be designed according to Subsection 13.
- k. It is recommended that chlorine or another disinfectant be added at the head of the treatment process to reduce/eliminate biological growth on the filters, taking into consideration possible impacts on DBP formation.
- l. A sampling tap shall be provided ahead of any treatment so a source water sample can be collected.
- m. Pressure gauges and sampling taps shall be installed before and after the bag or cartridge filters and before and after any pretreatment filters.
- n. An automatic air release valve shall be installed on top of the filter housing.
- o. Frequent start and stop operation of the bag or cartridge filter should be avoided. The following options are recommended:
 - 1) Install a slow opening and closing valve ahead of the filter to reduce flow surges.
 - 2) Reduce the flow through a bag or cartridge filter to as low as possible to lengthen filter run times.

- 3) Install a recirculation pump that pumps treated water back to a point ahead of the bag or cartridge filter. Care must be taken to make sure there is no cross-connection between the finished water and raw water.
- p. A minimum of two bag or cartridge filter housings should be provided for water systems that must provide water continuously.
- q. A pressure relief valve should be incorporated into the bag or cartridge filter housing.
- r. Complete automation of the treatment system is not required, but KDHE may require continuous monitoring of finished water quality and may further require that the plant be designed to automatically shut down when the finished water does not meet applicable regulations. It is important that a qualified operator be available to operate the treatment plant. A plan of action should be in place should the water quality parameters fail to meet applicable regulations.
- s. Bag or cartridge filters must be replaced when a pressure difference of 30 psi (210 kPa) or other pressure difference recommended by the manufacturer and acceptable to KDHE is observed. It should be noted that the pressure drop is not expected to increase linearly. KDHE may require continuous monitoring of the operating and/or differential pressures or other parameters such as instantaneous and total flows, and may establish other criteria for establishing the end of a filter run.
- t. Maintenance (O-ring replacement) shall be performed in accordance with the manufacturer's recommendations.
- u. Sterile rubber gloves and a disposable face mask covering the nose and mouth shall be worn when replacing or cleaning the cartridge or bag filters.
- v. The filter system shall be properly disinfected and water shall be ran to waste each time the cartridge or bag filter vessels are opened for maintenance.
- w. The following parameters shall be routinely monitored and recorded: instantaneous flow rate, cumulative flow through a given bag or cartridge, instantaneous operating pressure, differential pressure, and finished water turbidity.
- x. The operational and maintenance cost of bag and cartridge replacement must be considered when designing a system.

15. BIOLOGICALLY ACTIVE FILTERS – Biologically active filtration (or biofiltration), as used herein, refers to a filtration process that includes establishment and maintenance of biological activity within the filtration media. Treatment objectives may include: removal of biodegradable organic matter (naturally occurring or produced during treatment, e.g., during ozonation) to increase the stability of the finished water or to reduce DBP formation; oxidation of iron and manganese; removal of synthetic organic chemicals; and oxidation of ammonia nitrogen.

Biological activity can adversely impact removal of turbidity, particles and pathogens; disinfection practices; head loss development; filter run times; and taste and odor. Design and operation should ensure that aerobic conditions are maintained at all times. Biologically active filtration often includes the use of ozone as a pre-oxidant/disinfectant which breaks down natural organic materials into biodegradable organic matter and granular activated carbon filter media which may promote denser biofilms.

Biologically active filters may be considered based on pilot studies pre-approved by KDHE. The study objectives must be clearly defined and must ensure the microbial quality of the filtered water under all anticipated conditions of operation. The pilot study shall be of sufficient duration to ensure establishment of full biological activity, which may require three months or longer; and seasonal effects on water quality and temperature must be adequately addressed. The pilot study shall establish empty bed contact time, loading rates, backwash frequency and duration, backwash disinfectant residual level, and/or other parameters necessary for successful operation, as required by KDHE. The final design shall be based on the pilot-plant studies and shall comply with all applicable portions of Subsections 1 through 12 above.

K. SOFTENING

1. GENERAL CONSIDERATIONS – Softening should be considered for a raw water having a total hardness exceeding 300 mg/L as CaCO_3 and may be a desirable way to treat waters having lower concentrations of hardness. The decision of a PWSS to soften (or to not soften) is typically based on economic and aesthetic considerations, including detergent costs, scaling of water heaters and other appliances, and the needs of local industries. The alkalinity of the softened water should be at least 40 mg/L as CaCO_3 and preferably about 50 to 60 mg/L as CaCO_3 . In general, softening process selection is based upon the mineral qualities of the raw water (hardness, concentration and relative amounts of calcium, magnesium, and alkalinity), the desired finished water quality, requirements for disposal of solids or brine wastes, capital and O&M costs, and plant location. The applicability of the process chosen shall be demonstrated.
2. RELATED CRITERIA – The applicable design criteria for presedimentation, rapid mixing, flocculation, sedimentation, and filtration are included in Sections E to H and

J, respectively. For surface water and GWUI, the criteria are the same for lime softening and coagulation; but shorter minimum detention times are specified for sedimentation basins and solids contact basins used for lime softening of groundwater (Section H).

- a. Softening chemicals and recycled softening solids should be fed at the rapid mix basin along with the coagulant and/or coagulant aid as required for effective treatment when using conventional softening basins. Solids return flow rates vary depending on raw water quality, solubility equilibria, the physical and chemical properties of the solids produced by the softening process, and desired hardness levels.
- b. Softening chemicals may be added directly to the mixing compartment of solids contact units.

3. LIME SOFTENING – Process variations include: conventional lime softening (addition of lime to remove calcium carbonate hardness); lime-soda ash softening (with sodium carbonate also added, to remove non-carbonate hardness); excess-lime softening (with extra lime added to raise the pH high enough to remove the desired amount of magnesium hardness); two-stage treatment (a term that can refer to softening followed by two-stage recarbonation or to softening followed by or preceded by coagulation); and split-treatment (a term that can refer to treatment of a portion of the flow using excess-lime softening and the remainder of the flow with conventional softening or coagulation, or to treatment of a portion of the flow with softening while bypassing the remainder of the flow, typically to use the alkalinity in the bypassed flow to partially stabilize the softened water).

- a. The CO_2 concentration in the raw water should be accurately determined based on field measurements. If the concentration exceeds 10 mg/L, the possibility of CO_2 removal by aeration rather than by adding lime should be considered (Section P).
- b. Consultation with KDHE is required before proceeding with split-treatment. When split-treatment is used to reduce the chemical costs associated with magnesium removal, the magnesium concentration of the finished water should not exceed the values shown in Table V-2. When split-treatment is used to partially stabilize the treated water by using alkalinity in the bypassed flow to adjust the pH and alkalinity of the treated water, facilities to complete the stabilization process must be provided. For either type of split-treatment, the bypass line should be valved, metered, and sized to carry the total plant flow in case the need should arise to bypass the first stage of treatment, e.g., during an emergency.

TABLE V-2

**APPROXIMATE MAXIMUM ALLOWABLE MAGNESIUM HARDNESS
CONCENTRATIONS TO PREVENT PRECIPITATION
IN 140 °C HOT WATER (AWWA, 1971)**

pH @ 25 °C	Mg ⁺² , mg/L as CaCO ₃
9.0	65
9.2	57
9.4	51
9.6	45
9.8	40

- c. Stabilization of water that has been softened by treatment with lime is required (Section L). When two-stage recarbonation is used, settling must be provided between the first and second stages. The minimum settling basin detention time is 45 minutes, with a maximum overflow rate of 1,500 gpd/ft² (61,100 Lpd/m²) and a maximum weir loading of 15,000 gpd/ft (186,000 Lpd/m).
- d. Beneficial use of softening solids should be considered as an alternative to disposal.

4. CAUSTIC SODA SOFTENING

- a. Using caustic soda in place of lime results in consumption of only half as much alkalinity which can reduce or eliminate the need to use soda ash to soften low-alkalinity water.
- b. Other advantages of using caustic soda include its ease of storage, handling, and feeding along with much lower solids production.
- c. Disadvantages of using caustic soda include its higher cost (relative to lime) and increases in total dissolved solids and sodium in softened water. Additionally, if use of caustic soda results in higher softened water alkalinity concentrations this may increase the amount of carbon dioxide required to adjust finished water pH.

- d. Proposals to employ this process should include an analysis of the costs and benefits relative to those associated with the most applicable lime-softening process variation.
5. CATION EXCHANGE – Cation-exchange softening will only be approved on a case-by-case basis and the residual sodium and dissolved solids concentrations will be an important factor in this consideration. Silica gel resins should not be used for waters having a pH above 8.4 or containing less than 6 mg/L silica, and should not be used when iron is present. Iron, manganese, or a combination of the two, in the oxidized or unoxidized states, should not exceed 0.3 mg/L in the hard water treated by other cation exchange materials. Pretreatment for iron or manganese may be necessary and should be carefully evaluated. Water having 5 NTU or more turbidity should not be applied directly to the ion exchange softener. When the applied water contains a chlorine residual, the cation exchange resin shall be a type that is not damaged by residual chlorine. Phenolic resins should not be used. See Section R for design requirements pertaining to ion exchange systems used for IOC removal.
- a. DESIGN – The units may be pressure or gravity type, either upflow or downflow, and with automatic or manual regeneration. Automatic regeneration based on volume of water softened should be used unless manual regeneration is justified and approved by KDHE. A manual override shall be provided on all automatic controls. Units having a pipe that supplies water to the regeneration solution container also serving to siphon the solution to the softening unit will not be approved.
 - 1) Exchange Capacity – The design exchange capacity for hardness removal should be selected to minimize the resin regeneration and brine disposal requirements for the system.
 - 2) Depth of Media – The depth of the exchange material should not be less than 3 ft. (0.9 m).
 - 3) Flow Rates – Typical service flow rates for softening are 1 to 5 gpm/ft³ (134 to 670 L/min-m³) although higher rates are possible. The backwash rate should be selected to produce a bed expansion of no more than 100 percent.
 - 4) Freeboard – The freeboard will depend mainly upon the need for expansion of the resin during backwashing. Generally, the bottom of the washwater collector should be 2 ft. (0.6 m) above the top of the resin on downflow units.
 - b. BYPASS – A bypass should be provided for blending softened with unsoftened water to produce water of a desirable hardness. Totalizing meters must be installed on the bypass line and on each softener unit. The bypass

line must have a shutoff valve and should have an automatic proportioning or regulating device. In some installations, it may be necessary to treat the bypassed water to obtain acceptable levels of iron and/or manganese in the finished water.

- c. UNDERDRAINS AND SUPPORTING GRAVEL – These components should conform to applicable criteria for rapid rate gravity filters (Section J).
- d. CROSS-CONNECTION CONTROL – Backwash, rinse, and air relief discharge pipes should be installed in a manner that is appropriate to their intended use and prevents backsiphonage.
- e. SAMPLING TAPS – Smooth-nosed sampling taps shall be located to provide samples of softener influent, effluent, and blended water. The sampling taps for blended water should be located at least 20 ft. (6.1 m) downstream from the point of blending. Sampling taps should be provided on the brine tank discharge piping.
- f. BRINE DISTRIBUTION – Facilities should be included for even distribution of the brine over the entire surface of the upflow or downflow units.
- g. BRINE PUMP OR EDUCTOR – An eductor may be used to transfer brine from the brine tank to the softeners. If a pump is used, a brine measuring tank or means of metering should be provided to verify the volume of brine used.
- h. SALT AND BRINE STORAGE TANKS
 - 1) Salt dissolving (brine) tanks and wet salt storage tanks must be covered and corrosion resistant.
 - 2) The make-up water inlet must be protected from backsiphonage. Water for filling the tanks should be distributed over the entire surface by pipes above the maximum brine level in the tank. The tanks should be provided with an automatic declining level control system on the make-up water line.
 - 3) Wet salt storage basins must be equipped with manholes or hatchways for access and for direct dumping of salt from truck or railcar. Openings must be provided with raised curbs and watertight covers having overlapping edges similar to those required for finished water reservoirs.

- 4) Overflows, where provided, must be protected with corrosion resistant screens and must terminate with either a turned-down bend having a proper free fall discharge or a self-closing flap valve.
 - 5) Two wet salt storage tanks or compartments designed to operate independently should be provided.
 - 6) The salt shall be supported on graduated layers of gravel placed over a brine collection system.
 - 7) Alternative designs that are conducive to frequent cleaning of the wet salt storage tank may be considered.
- i. **SALT AND BRINE STORAGE CAPACITY** – Total salt storage should have sufficient capacity to store in excess of 1.5 truckloads or carloads of salt and provide for at least 30 days of operation.
 - j. **WASTE DISPOSAL** – Suitable disposal must be provided for brine waste. Where the volume of spent brine must be reduced consideration may be given to using a portion of the spent brine for a subsequent regeneration.
 - k. **CONSTRUCTION MATERIALS** – Pipes and contact materials must be resistant to the aggressiveness of salt. Plastic and red brass are acceptable piping materials. Steel and concrete must be coated with a non-leaching protective coating that is compatible with salt and brine.
 - l. **HOUSING** – Bagged salt and dry bulk salt storage shall be enclosed and separated from other operating areas in order to prevent damage to equipment.
- L. STABILIZATION** – An unstable water is one that changes significantly in quality during treated water storage or in the distribution system. A chemically unstable water may form scales in the distribution system (e.g., due to precipitation of CaCO_3 or other solids), corrode the distribution system or its components (which may increase lead and copper beyond acceptable levels), or become turbid or discolored (e.g., due to precipitation of iron or manganese). A biologically unstable water is one that supports the growth of bacteria, which can cause corrosion, taste and odor problems, high heterotrophic plate counts, loss of chlorine residual, and other adverse effects. A water may be naturally unstable (e.g., a source water may contain elevated levels of CO_2 or H_2S) or it may become unstable as a result of treatment (e.g., chemical addition may raise or lower the pH, and the use of a strong oxidant, such as ozone, may produce organic acids that are biodegradable). Water that is unstable, naturally or as a result of treatment, shall be stabilized. The expected quality of treated water shall be evaluated to determine what, if any, treatment is needed.

1. THE CaCO_3 SATURATION INDEX (SI) – The SI (often referred to as the Langlier Index) is widely used, especially in the Midwestern U.S., to indicate whether a water has a tendency to precipitate or dissolve calcium carbonate. Waters having a negative SI tend to dissolve CaCO_3 and to be corrosive, while those with a positive SI tend to precipitate CaCO_3 and to be scale forming. Instructions for calculating the SI can be found in *Standard Methods* (APHA *et al.*, 2005). The SI is imperfect, in that various factors affecting precipitation of CaCO_3 are ignored, e.g., the concentrations of phosphate and natural organic matter present in the water; but it is a useful reference point for the design of stabilization facilities and for monitoring and controlling water quality in a distribution system.

In general, waters having a slightly positive SI tend to be the most stable; but caution must be exercised lest too much CaCO_3 be deposited in the distribution system. Instructions for calculating the CaCO_3 precipitation potential of a water (or CCPP) can also be found in *Standard Methods*. A positive CCPP of 4 to 10 mg/L is typically recommended, but higher values may be needed to prevent corrosion, especially for water supplies high in TDS. To better resist changes in quality, it is also recommended that the water in the distribution system have concentrations of both calcium and alkalinity of at least 40 mg/L as CaCO_3 and low concentrations of chloride and sulfate (Merrill and Sanks, 1977). Furthermore, pH values associated with minimum buffer intensity (e.g., pH 8.0 to 8.5 for water at 68 °F (20 °C)) should also be avoided, as noted by Schock (1999). In order to produce a stable finished water, it may be necessary to adjust the pH and alkalinity of the finished water or to add chemicals, such as polyphosphates, that help stabilize the water.

2. STABILIZATION OF SOFTENED WATER – Lime softening is normally followed by stabilization, with carbon dioxide or sulfuric acid being added to reduce the pH; typically to 8.5 to 9.0, resulting in a slightly positive SI. When carbon dioxide is used, this process is typically referred to as recarbonation. When excess-lime softening is employed to remove magnesium, two-stage recarbonation is sometimes used. In the first stage, carbon dioxide is added to reduce the pH to 10.0 to 10.6, precipitating additional CaCO_3 that is removed by sedimentation. In the second stage, additional carbon dioxide is added to reduce the pH to a lower value, typically 8.5 to 9.0. If sulfuric acid is used, consideration should be given to its impact on finished water alkalinity and on the bicarbonate to sulfate ratio and its potential effect on copper corrosion (Schock, 1999). Submerged gas burners are not approved for new installations, and on-site generation of carbon dioxide is discouraged. Gas (under vacuum) or solution feed systems are recommended; but sulfuric acid may also be used (except in the first stage of two-stage recarbonation).

a. Recarbonation basin design should provide:

- 1) A total detention time of 20 minutes;
- 2) A mixing/dissolution compartment; and

3) A reaction compartment.

The mixing/dissolution compartment for carbon dioxide gas diffuser feed systems should provide at least 3 minutes of contact time and have a diffuser submergence depth of at least 7.5 ft. (2.3 m) but not a depth greater than what is recommended by the manufacturer. Other appropriate means of dissolution, e.g., direct injection into a pressurized pipe or the use of a solution feed system, may be proposed.

- b. Adequate precautions must be taken to prevent carbon dioxide used in the recarbonation process from accumulating to dangerous levels, especially in enclosed spaces.
 - c. Provisions should be made for draining the recarbonation basin and removing accumulated solids.
 - d. Split-treatment for partial control of stability may be feasible, but the treated water, including bypass flows, must be properly filtered and disinfected as described in Subsection B.4 of this chapter; and facilities to complete the stabilization process must be provided.
 - e. Due consideration must be given to diffuser design and location, pressure, flow, flow ratio, submergence, reaction and control times, temperature (solubility), and precipitation potential where direct injection or solution feed systems are employed. Consultation with the feed system supplier early on in the design process is strongly recommended to identify any special requirements.
3. CORROSION CONTROL FOR LEAD AND COPPER – As noted in Subsection B.5 of this chapter, all PWSSs are required to optimize corrosion control treatment to minimize lead and copper. This may involve adjusting pH and alkalinity, depositing a thin film of CaCO_3 on pipe surfaces (by adjusting the SI to a slightly positive value), or feeding chemicals such as orthophosphate, zinc orthophosphate, and blended phosphates (Schock, 1999; USEPA, 2003b).
4. CHEMICAL ADDITION – Many different chemicals may be used for stabilization, including: acids (usually carbon dioxide or sulfuric acid, to lower pH); bases (usually lime, soda ash, or caustic soda, to increase pH and/or alkalinity); calcium carbonate or sodium bicarbonate (to increase alkalinity, though this is rarely, if ever, necessary for water supplies in Kansas); antiscalants (usually polyphosphates); and chemicals used as corrosion inhibitors or sequestering agents (e.g., orthophosphate, sodium silicate, blended phosphates, and zinc orthophosphate).
- a. Chemicals used for stabilization must be appropriate for use in the production of drinking water (Subsection A.4.a.(1) of Chapter IX).

- b. Any proprietary compound must be approved by KDHE prior to use.
 - c. Chemical feeders must be approved by KDHE (Chapter IX on Chemical Storage, Handling, and Disposal).
 - d. Stock phosphate and polyphosphate solutions should be covered and disinfected by carrying a free chlorine residual of approximately 10 mg/L. Phosphate solutions having a pH of 2.0 or less may be exempted from this requirement by KDHE.
 - e. Polyphosphate may be added for treatment purposes, e.g., to prevent encrustation of filter media, to sequester iron, or to reduce corrosion or scale formation in the distribution system. The dosage and point of application must be carefully selected to achieve the desired purpose and to avoid unintended consequences. For example, adding polyphosphate prior to filtration can cause a significant increase in filtered-water turbidity. In this case, it may be necessary to use other means to reduce filter encrustation and to add the polyphosphate after filtration.
5. CARBON DIOXIDE REMOVAL BY AERATION – The carbon dioxide content of aggressive waters may be reduced by aeration (Section P).
6. INSTABILITY DUE TO BIOCHEMICAL ACTION IN THE DISTRIBUTION SYSTEM – Unstable water resulting from the bacterial decomposition of organic matter, biochemical action within tubercles or other deposits, oxidation of ammonia (nitrification), and reduction of sulfate can usually be prevented by maintaining an adequate chlorine residual throughout the distribution system. When a combined chlorine residual is maintained in the distribution system, optimizing operating practices, e.g., maintaining proper chlorine-to-ammonia ratios and monitoring free ammonia and chloramine residuals within the distribution system, will help ensure that nitrifying conditions do not develop. If ozonation or another strong oxidation process is used, it may be necessary, depending on the concentration and characteristics of organic matter in the raw water and on the oxidant dosage employed, to provide additional treatment to reduce the concentration of biodegradable matter entering the distribution system, e.g., to employ biological filtration (Subsection J.15) following the oxidation process or to remove more of the precursor materials using enhanced coagulation or adsorption on GAC.
7. OPERATIONAL CONTROL OF STABILITY – Laboratory equipment shall be provided for determining the effectiveness of stabilization.

M. DISINFECTION

All drinking water supplied to the public by a public water supply system must be disinfected (KAR 28-15-19(a)). Disinfection requirements depend upon the source and quality of the

supply. PWSSs using surface water or GWUI must use a treatment approach based on credits for removal and/or inactivation of *Giardia lamblia*, *Cryptosporidium*, and viruses (KAR 28-15a-70). PWSSs using groundwater must comply with the requirements of the Ground Water Rule (GWR), which under certain conditions may require virus removal and/or inactivation for PWSSs having fecally contaminated source waters or having significant deficiencies (40 CFR 141.400 et seq.). All PWSSs employing chlorination must maintain a specified level of chlorine in the distribution system (KAR 28-15-19(b)). These requirements are described in greater detail in Subsections 1 through 4 below.

Single or multiple disinfectants can be used to meet the inactivation requirements. Approved disinfectants include free chlorine, combined chlorine, chlorine dioxide, ozone and ultraviolet (UV) light. Combined chlorine is not permissible for primary disinfection. Chlorine dioxide is not permissible as a residual disinfectant. The use of heat, extremes in pH, metals, surfactants, potassium permanganate, hydrogen peroxide, iodine, or bromine for the purpose of disinfection is not permissible. Other disinfecting agents will be considered if they are proven safe and effective, reliable application equipment is available, and a testing procedure suitable for determining an effective dose and/or residual is recognized in the most recent edition of *Standard Methods* (APHA *et al.*, 2005). Public notification must be given, especially to hospitals, kidney dialysis facilities, and fish breeders, before changing the residual disinfectant from free chlorine to combined chlorine.

Design considerations for gas chlorination facilities and for feeding chemicals (including disinfectants, such as sodium hypochlorite, and chemicals used to form disinfectants, such as sodium chlorite and anhydrous ammonia) are addressed in Chapter IX. Design considerations for chlorine dioxide, ozone, and UV installations are addressed in Subsections 5, 6 and 7, respectively.

1. CT REQUIREMENTS

- a. One basis for determining the acceptability of disinfection is to evaluate the composite CT (inactivation ratio) for the system under two extremes of operation. These are summer and winter operations at maximum hourly flow. For new treatment plants, CTs are calculated for these temperature and flow extremes using the design values of detention times and disinfectant residuals. For upgrading existing facilities, CTs are calculated using existing plant data and design values for new or modified treatment units. Before significant changes in disinfection practice are made to an existing system, a system is required to develop a disinfection profile (if the system has an annual average TTHM or HAA5 concentration \geq 80 percent of the MCL) (USEPA, 1999a), establish a disinfection benchmark, and consult with KDHE to obtain its approval prior to proceeding with the changes (40 CFR 141.172, 141.542 and 141.709).

For both new and existing facilities, the calculated CT values are compared with USEPA's CT requirements to determine if the required log inactivations

for *Giardia lamblia* and viruses will be achieved (USEPA, 1991)(40 CFR 141.74). The CT values for pH 9 and for a free chlorine residual of 3 mg/L must be used for a sample pH greater than 9 or a free chlorine residual greater than 3 mg/L, respectively.

- b. Design of treatment facilities to achieve the required CT values must also take into consideration the contact time that needs to be provided and the location of the contact basin.

- 1) Minimum Contact Time – The contact time needed to meet CT requirements depends on several factors including the disinfectant residual concentration, temperature, pH and water quality. The minimum disinfectant contact time in straight-run pipelines is calculated based on the assumption of plug flow (i.e., by dividing the internal volume of the pipeline by the maximum hourly flow through the pipeline). Contact times for mixing basins, treatment basins, storage reservoirs, looped pipe networks, or other types of contact structures shall be determined by tracer studies or an equivalent demonstration. Since ozone residuals decay rapidly and are strongly dependent on water quality, the contact time required for ozone inactivation of microbes must be determined by pilot or in-plant studies (Subsection M.6). Basins used for disinfection should be designed to minimize short-circuiting. Baffling can be added to existing basins to minimize short-circuiting and to increase the effective contact time.

Credit for contact time in water storage structures (e.g., elevated and ground storage tanks, or standpipes) will only be granted for those located prior to the point of entry to the distribution system (or first customer) (KAR 28-15a-2). No credit will be granted for contact time in storage structures that have a single inlet/outlet line and/or where at any time only a portion of the total treated water volume flowing to the distribution system enters the storage structure.

- 2) Contact Basin Location – A contact basin used for CT credit may be located before or after filtration. In determining the location of the basin,
 - a) Adequate consideration must be given to the increase in DBP formation associated with disinfection of unfiltered water, the detrimental effects of particulate matter on the disinfection process, and short-circuiting associated with the concurrent use of process equipment in basins used for CT credit when a contact basin is located prior to filtration.

- b) Provisions must be included in the treatment sequence to ensure that both iron and manganese are adequately oxidized and their precipitated forms removed through sedimentation or filtration when a contact basin is located after filtration.
- c) The design of a post-filtration contact basin must ensure adequate contact time regardless of the manner in which transfer and high service wells and pumps are operated.
- d) The design of a post-filtration contact basin must ensure that post-filtration treatments do not adversely impact finished water quality.
- e) Post-filtration contact basins shall be enclosed, irrespective of being located inside a structure or out-of-doors, to preclude degradation of finished water quality by sources of contamination external to the contact basin.

2. GROUNDWATER (EXCLUDING GWUI)

- a. KDHE must determine if a groundwater resource is not GWUI (i.e., if it is exempt from the SWTR).
- b. All supplies shall be disinfected before delivery to the distribution system. Under certain conditions, the requirements of the GWR may require PWSSs having fecally contaminated source waters or having significant deficiencies to achieve at least a 4-log removal and/or inactivation of viruses (40 CFR 141.400 et seq.). As a minimum at plants treating groundwater, provisions shall be made for applying the disinfectant to the disinfection contact basin inlet and to the treated water entering the distribution system.
- c. Water from several wells may be combined to facilitate the disinfection process. However, if any well is determined to be GWUI, the combined flow must be filtered and disinfected in accordance with KAR 28-15a-70 unless such treatment is provided for the water deemed to be GWUI prior to the point where the flows are combined.
- d. A sampling tap shall be provided to collect a sample of the disinfected water before it enters the distribution system. The sampling tap shall be located at least 10 pipe diameters downstream from the point of disinfectant addition or at a location downstream of where the mixing of the disinfectant and treated water is complete.

3. SURFACE WATER AND GWUI – Disinfection of these sources can be accomplished using filtration in combination with one or more disinfectants at one or

more points in the treatment, storage, and distribution systems. The choice of disinfectant(s) and application point(s) will depend not only on microbial inactivation requirements but also on the need for predisinfection or preoxidation, the need to control DBP formation, the need to provide sufficient operational flexibility to deal with variations in water quality and temperature, and the need to maintain a minimum disinfectant residual throughout the distribution system. PWSSs using surface water or GWUI as a source of supply and using chlorine as the primary disinfectant should consider maintaining a combined chlorine residual throughout the distribution system in order to control DBP formation.

- a. **PREDISINFECTION AND PREOXIDATION** – Predisinfection (the application of a disinfectant prior to clarification) has historically been practiced by Kansas PWSSs to enhance disinfection and to control problems associated with biological growths, such as slime formation and production of taste and odor causing substances. Preoxidation may be necessary when treating waters containing elevated levels of substances such as iron, manganese, and hydrogen sulfide, or to oxidize naturally occurring or synthetic organic chemical contaminants. Due to increasingly stringent regulatory limits on DBPs, predisinfection or preoxidation with free chlorine is no longer a viable option for many systems. Thus, other disinfectants and/or oxidants, some of which also produce DBPs, may need to be considered. Proposals to practice chlorine-free predisinfection or preoxidation will be evaluated by KDHE on a case-by-case basis. And approval of CT credit for such proposals will also be evaluated by KDHE on a case-by-case basis. Relevant factors for evaluating such proposals include:
 - 1) The impact on DBP formation in a particular source water and whether the PWSS will be able to comply with all applicable regulatory limits on DBPs.
 - 2) The purpose of chlorine-free predisinfection or preoxidation and whether other alternative chemicals, processes, or operational measures can achieve the desired objective while producing significantly lower levels of DBPs.
- b. **PRIMARY DISINFECTION** – Primary disinfection is the inactivation of pathogenic microorganisms, the effectiveness of which is evaluated by performing the CT calculations described above. PWSSs using surface water or GWUI must achieve at least a 3-log (99.9%) removal and/or inactivation of *Giardia lamblia* and a 4-log (99.99%) removal and/or inactivation of viruses (KAR 28-15a-70). Filtration is required for removal of *Cryptosporidium* (KAR 28-15a-170 or KAR 28-15a-500), but additional treatment for removal or inactivation of *Cryptosporidium* may be required, depending on the system's bin classification (40 CFR 141.700 et seq.). At plants treating surface water, a disinfectant is typically added ahead of the

filters to control biological growth on the filter media, and after filtration, prior to storage in the clearwell, to protect the water during storage and to produce the desired residual entering the distribution system. To provide operational flexibility at plants treating surface water, especially during emergencies or episodes of unusual water quality, provisions shall be made for applying the disinfectant to the raw water, settled water, filtered water, and water entering the distribution system.

Chlorinator capacity for primary disinfection should not be less than 10 mg/L at maximum flow. Depending on raw water quality and the level of treatment provided, higher capacities may be needed to ensure adequate disinfection at all times. The chlorinator capacity shall be such that a free chlorine residual of at least 2 mg/L can be maintained in the water, once all demands are met, after a contact time of at least 30 minutes when maximum flow coincides with maximum chlorine demand.

- c. SUPPLEMENTAL DISINFECTION – Regardless of the primary disinfectant used, chlorination facilities may be required for repumped storage reservoirs and booster pump stations in the distribution system. Other chlorination stations may be required to maintain satisfactory chlorine residuals in some distribution systems.

4. CHLORINE RESIDUALS AND USE OF CHLORAMINES

- a. Chlorine residuals at distant points in the distribution system shall not be less than 0.2 mg/L for free chlorine or 1.0 mg/L for combined chlorine (KAR 28-15-19(b)). Higher residuals may be needed, depending on water quality, temperature, and pH, to control undesirable growths of organisms (e.g., nitrifying bacteria) in the distribution system. If ammonia is present in the raw water, as is sometimes the case for groundwater supplies, its concentration must be considered in the design and operation of the chlorination process, and the monitoring method used to measure the residual must be capable of distinguishing between free chlorine and combined chlorine.
- b. Guidelines for treatment using chloramines (as a residual disinfectant in the treatment plant and/or in the distribution system) are:
 - 1) Sufficient ammonia or an ammonium compound should be added to convert free chlorine to the combined form at a location beyond the point where primary disinfection has been completed and where adequate mixing occurs. A $\text{Cl}_2:\text{NH}_3\text{-N}$ applied weight ratio of 3:1 to 5:1 is generally considered to be the optimum range for the formation of monochloramine under common chloramination treatment conditions. Lower ratios may promote nitrification in the distribution

system; higher ratios favor the formation of di- and trichloramine that can potentially cause taste and odor problems. Where applicable (e.g., GWUI drawn from a typical alluvial aquifer), the $\text{NH}_3\text{-N}$ in the raw water must be taken into account in controlling the $\text{Cl}_2\text{:NH}_3\text{-N}$ ratio. Ammonia or an ammonium compound should be fed after the chlorine but before the treated water enters the clearwell.

- 2) Careful consideration must be given to the adequacy of mixing and pH control (to minimize loss of chlorine and formation of di- and tri-chloramine); to the chloramine decay rate and the average residence time in the distribution system (to maintain an adequate residual throughout the distribution system); and to the need to control biological growths in the distribution system. The combined form of chlorine is much less efficient than free chlorine as a disinfectant, and a correspondingly higher concentration must be maintained to accomplish the desired degree of protection from pathogens and to prevent biological growths in the distribution system. This is reflected in the larger required CT value for chloramine disinfection as compared to free chlorine at the same pH and water temperature to achieve a desired level of inactivation of *Giardia lamblia* or viruses (USEPA, 1991)(40 CFR 141.74).

5. CHLORINE DIOXIDE

- a. GENERATORS – Chlorine dioxide generators shall be factory assembled pre-engineered units producing a minimum chlorine dioxide purity of 95 percent. Excess free chlorine (if used) shall not exceed three percent of the theoretical stoichiometric concentration required. The generators (and the associated storage and handling equipment) must be designed to prevent the occurrence of explosive levels of chlorine dioxide (approximately 8 percent and higher in air or in the head space over the solution).
- b. OTHER DESIGN REQUIREMENTS
 - 1) The design shall comply with the applicable portions of Subsections 1 through 4, above.
 - 2) Provision must be made for systems to comply with the MRDL for chlorine dioxide (KAR 28-15a-65) and the MCL for chlorite (KAR 28-15a-64). While it is important that chlorine dioxide be consumed prior to the finished water entering the distribution system, it is important to note that it can also be regenerated in the distribution system through the reaction of residual chlorite with free chlorine. The concentration of chlorate (which can be present as an impurity in chemical feed

stocks or produced by the generator, by sunlight, or by reactions with other oxidants) should be minimized.

- 3) Since chlorine dioxide (like free chlorine) is volatile, provision must be made to prevent the accumulation of chlorine dioxide in enclosed areas.
 - 4) Since chlorine dioxide is photochemically degraded, KDHE strongly recommends that contact basins used for CT credit ahead of filtration be shielded from sunlight. Contact basins after filtration must be enclosed; thus they will be shielded by design.
 - 5) Due to the highly reactive nature of chlorine dioxide and the chemicals typically used to generate it, careful attention must be given to safety and to the materials used in construction and maintenance of the generators, storage facilities, and piping runs. See Chapter IX (Chemical Storage, Handling, and Application), Gates (1998), and White (1999) for more detailed information.
- c. PUBLIC NOTIFICATION – Notification of a change in disinfection practices and the schedule for the change shall be made known to the public, particularly to hospitals, kidney dialysis facilities, and fish breeders, as chlorine dioxide and its byproducts may have effects similar to those of chloramines.

6. OZONATION – The ozonation process consists of four primary components: ozone generator, feed-gas supply, ozone contactor and ozone destruct system. The ozone generator is the heart of the ozone process and is in general unique to each manufacturer. The feed-gas supply, ozone contactor and ozone destruct systems are not necessarily manufacturer specific; but, for new installations they are generally supplied by the manufacturer that provides the ozone generator.

Up until the early to mid 1990's, ozone systems were generally air- or oxygen enriched air-fed designs; however, the systems of choice are now oxygen-fed designs as a result of advances in ozone generator design that have reduced energy consumption and increased ozone generator efficiency (Rakness, 2005). The choice should be made after due consideration of energy and equipment costs. Ozone production is an energy intensive process and substantial economies in electrical usage, reduction in equipment size, and waste heat removal requirements can be obtained by using oxygen-enriched air or pure oxygen, and by operating at increased electrical frequency.

Ozone contactors have historically been constructed as over-under baffled basins with ozone gas introduced into the leading compartment through a bubble-diffuser grid. Sidestream ozone dissolution injection systems are more common today in new installations because they are more efficient in their delivery of ozone to the contactor as compared to gas-fed, bubble-diffuser feed systems (Rakness, 2005).

Ozone destruct systems treat off-gases collected from the ozone process. Ozone in the collected off-gases is destroyed by catalytically converting it to oxygen prior to discharge to atmosphere.

As a minimum, bench-scale studies shall be conducted to determine the minimum and maximum ozone dosages for disinfection, for taste and odor control (Section N), or oxidation of chemical contaminants, unless sufficient data are available from tests performed on the same water source. Pilot-plant studies shall be conducted when necessary to document ozone's potential benefits (e.g., lower concentrations of certain DBPs (KAR 25-15a-64), lower coagulant demand, and increased biodegradability of organic compounds in conjunction with biologically active filters), costs, or potential disadvantages (e.g., formation of bromate and biodegradable organic matter). The effects of variations in water quality must be adequately addressed; and the effect of pH should be carefully evaluated, since ozone's reactivity (and therefore its residual concentration, used to calculate CT) is strongly pH dependent. Consideration shall be given to multiple points of ozone addition. Special care must be taken during bench and pilot-scale studies to ensure accurate results. Particularly sensitive measurements include gas and water flow rates and the ozone concentrations in both the gas and the water. The following items shall be addressed in the design:

a. AIR FEED SYSTEM

- 1) General – Air handling equipment on conventional low pressure air feed systems shall consist of an air compressor, water/air separator, refrigerant dryer, heat reactivated desiccant dryer, and filters. Some package ozonation systems for small plants may work effectively operating at high pressure without the refrigerant dryer and with a heatless desiccant dryer. In all cases the designer must ensure that the maximum dew point of -76 °F (-60 °C) will not be exceeded at any time.
- 2) Air Compression
 - a) Air compressors shall be of the liquid-ring or rotary lobe, oil-less, positive displacement type or dry rotary screw compressors. Generally, dry rotary screw compressors are utilized by large systems. However, liquid ring compressors have been installed on some large systems.
 - b) The air compressors shall have the capacity to simultaneously provide for maximum ozone demand, provide the air flow required for purging the desiccant dryers (where required) and allow for standby capacity.

- c) Air feed for the compressor shall be drawn from a point protected from rain, condensation, mist, fog, and contaminated air sources to minimize the moisture and hydrocarbon content of the air supply.
- d) A compressed air aftercooler and/or entrainment separator with automatic drain shall be provided prior to the dryers to reduce the water vapor.
- e) A back-up air compressor must be provided so that ozone generation is not interrupted in the event of a breakdown.

3) Air Drying

- a) Dry, dust-free and oil-free feed gas must be provided to the ozone generator. Dry gas is essential to prevent formation of nitric acid, to increase the efficiency of ozone generation, and to prevent damage to the generator dielectrics. Sufficient drying to a maximum dew point of -76 °F (-60 °C) must be provided at the end of the drying cycle.
- b) Drying for high pressure systems may be accomplished using heatless desiccant only. For low pressure systems, a refrigeration air dryer in series with heat-activated desiccant dryers shall be used except with a chilled water aftercooler. In the latter case, the chilled water system serves as the cooling water supply for the ozone generators and for the compressed air aftercoolers.
- c) A refrigeration dryer capable of reducing inlet air temperature to 40 °F (4 °C) shall be provided for low pressure air preparation systems. The dryer can be of the compressed refrigerant type or chilled water type.
- d) For heat-reactivated desiccant dryers, the unit shall contain two desiccant filled towers complete with pressure relief valves, two four-way valves, and a heater. In addition, external type dryers shall have a cooler unit and blowers. The size of the unit shall be such that the specified dew point will be achieved during a minimum adsorption cycle time of 16 hours while operating at the maximum expected moisture loading conditions.
- e) Multiple air dryers shall be provided so that the ozone generation is not interrupted in the event of dryer breakdown.

- f) Each dryer shall be capable of venting dry gas to the atmosphere, prior to the ozone generator, to allow start-up when other dryers are on-line.

4) Air Filters

- a) Air filters shall be provided on the suction side of the air compressors, between the air compressors and the dryers and between the dryers and the ozone generators.
- b) The filter before the desiccant dryers shall be of the coalescing type and be capable of removing solid or liquid particles larger than 0.3 microns in diameter. The filter after the desiccant dryer shall be capable of removing all particles greater than 0.1 microns in diameter, or smaller if specified by the generator manufacturer.

- 5) Air Preparation Piping – Piping in the air preparation system can be common grade steel, seamless copper, stainless steel, or galvanized steel. The piping must be designed to withstand the maximum pressure in the air preparation system.

b. HIGH PURITY OXYGEN FEED

- 1) General – High-purity oxygen is most commonly obtained by evaporating high-purity liquid oxygen (LOX), but it can also be generated on-site using pressure swing adsorption (PSA), vacuum swing adsorption (VSA), thermal swing adsorption (TSA), or cryogenic separation. The designer should justify the method employed, taking into consideration system cost and performance for the specific application involved. Noise attenuation may be necessary when using PSA, VSA, or cryogenic systems.

Major components of LOX systems are storage tank(s), vaporizers and a supplemental high pressure air supply. The design of LOX storage tanks and vaporizers is addressed in the subsections immediately below. LOX feeding facilities are commonly provided on a lease basis from the LOX supplier. Bulk LOX storage facilities shall comply with all Federal, State and local requirements. Specifications for LOX used in the generation of ozone may be found in AWWA Standard B304.

Of particular importance in the design of high-purity oxygen systems are design and construction, location, operation, placarding, safety and security.

2) LOX

- a) Tanks can be either vertical or horizontal depending on capacity and site limiting conditions. Typical vertical and horizontal storage tank sizes are 3,000 to 13,000 gallons (11,400 to 49,200 L) and 10,000 to 40,000 gallons (37,900 to 151,400 L), respectively. Tanks are typically sized for 15 days of storage at the minimum operating capacity.
- b) The daily rate at which oxygen can be vented during periods of minimum usage must also be considered. During minimum oxygen usage, tank warming can boil off oxygen at a rate of about 0.3% to 0.5% of the storage tank capacity each day. Oxygen will be vented to the atmosphere through the tank's pressure relief valve when the boil off rate exceeds the oxygen usage rate (Rakness, 2005).
- c) Tanks, piping and related appurtenances should be appropriately insulated to minimize temperature rise and boil-off.
- d) Tanks must be adequately protected from over pressure and vacuum conditions.
- e) Provisions to protect tanks from collision due to normal traffic or during deliveries shall be included.
- f) Bulk storage tanks and related facilities shall be properly located to ensure safe operation.

3) Liquid Oxygen Vaporizers

- a) A minimum of two vaporizers must be provided. Each must be capable of meeting the maximum oxygen usage rate with the other vaporizer either defrosting or on standby. Where there are more than two vaporizers, the maximum oxygen usage rate must be met with the largest vaporizer either defrosting or on standby.
- b) Vaporizers may be vertical or horizontal, and single or multiple staged.
- c) Ambient air vaporizers are recommended. Water-bath vaporizers are discouraged as they are subject to failure during freezing conditions.

- d) Designs for colder climates should include at a minimum trim heaters and vaporizer covers to assist with deicing during winter operations.
- e) Delivery pressure of gaseous oxygen shall be controlled to ensure proper flow and protect all downstream equipment. Mechanical and pilot-operated valves are common types of pressure-reducing valves.
- f) Gaseous oxygen must be filtered to remove particles greater than 0.1 microns in diameter, or smaller if specified by the generator manufacturer.

4) Supplemental High-Pressure Air Supply

- a) A high-pressure supplemental air supply system is typically included as the presence of nitrogen in the appropriate balance can, depending on the liquid oxygen technology, increase the efficiency of a LOX-fed ozone generator by 10-20% (Rakness, 2005).
- b) The high-pressure air provided must be clean and dry. The steps necessary to achieve this are similar to those for air-fed ozone systems in Subsection 6.a above.
- c) High-pressure air is typically injected into the gaseous oxygen supply header line downstream of the pressure control valve and ahead of the filters.

5) Safety – The facility shall be properly located to ensure its safe operation. Of particular importance is placarding which prohibits smoking and open flames. Additional warning placards or other signage shall be posted as is deemed necessary.

6) Security – The site must be adequately secured to prevent vandalism and unauthorized entry.

c. OZONE GENERATOR

1) Capacity

- a) The production rating of the ozone generators shall be stated in mass per unit time (lbs/day or kg/day) and energy per unit mass (hp-hr/lb or Wh/kg) at a maximum cooling water temperature and maximum ozone concentration.

- b) The design shall ensure that the minimum concentration of ozone in the generator exit gas will not be less than one percent (by weight), unless the system is specifically designed to operate at less than one percent.
 - c) Generators shall be sized to have sufficient reserve capacity so that the system does not operate at peak capacity for extended periods of time. This can result in premature breakdown of the dielectrics.
 - d) The production rate of ozone generators will decrease as the temperature of the coolant increases. If there is to be a variation in the supply temperature of the coolant throughout the year, then curves or other data shall be used to determine production changes due to the temperature change of the supplied coolant. The design shall ensure that the generators can produce the required ozone at maximum coolant temperature.
 - e) Appropriate ozone generator backup equipment must be provided.
- 2) Electrical – The generators can be low, medium, or high frequency type. Specifications shall require that the transformers, electronic circuitry, and other electrical hardware be proven, high quality components designed for ozone service.
 - 3) Cooling – The required water flow to an ozone generator varies with the ozone production. Normally, unit design provides a maximum cooling water temperature rise of 5 °F (2.8 °C) except where a chilled water cooling system is used. The cooling water must be properly treated to minimize corrosion, scaling, and microbiological fouling of the water side of the tubes. A closed loop cooling water system is often used to ensure that proper water conditions are maintained. Where cooling water is treated, cross-connection control shall be provided to prevent contamination of the PWSS.
 - 4) Materials – To prevent corrosion, the ozone generator shell and tubes shall be constructed of 316L stainless steel.
- d. OZONE CONTACTORS – The selection or design of the contactor and method of ozone application depends on the purpose for which the ozone is to be used.

1) Contactors

- a) When disinfection is the primary purpose, a minimum of two contact chambers, each equipped with baffles to prevent short-circuiting and induce countercurrent or cocurrent flow, shall be provided. A larger number of contactors may be warranted to improve hydraulic efficiency (T_{10}/T value, where T_{10} is the time required for 10 percent of the influent water to pass through a series of contact basins having an overall contact time of T).
- b) The minimum contact time shall be 10 minutes. A shorter contact time may be approved by KDHE if justified by appropriate design and CT considerations.
- c) For ozone applications in which precipitates are formed, such as with iron and manganese removal, porous diffusers should be used with caution.
- d) Where taste and odor control is of concern, multiple application points and contactors shall be considered.
- e) Contactors should be separate closed vessels. The contactor must be kept under negative pressure and sufficient ozone monitors shall be provided to protect worker safety. Placement of the contactor where the entire roof is exposed to the open atmosphere is recommended. The ozone process shall at a minimum be housed in a separate room. In no case shall the contactor roof be a common wall, whole or in part, with a separate room above the contactor, except the room used to house ozonation and related equipment; nor should the roof covering the contactors extend over adjacent rooms. Entrances and climate and noise reduction control systems shall be separate.
- f) Large contact vessels should be made of reinforced concrete. All reinforcement bars shall be covered with a minimum of 3.0 inches (7.6 cm) of concrete to insulate the reinforcement bars from ozone. Smaller contact vessels can be made of stainless steel or other material which will be stable in the presence of residual ozone and ozone in the gas phase above the water level.
- g) Where necessary a system shall be provided between the contactor and the off-gas destruct unit to remove froth from

the air and return it to the contactor or another location acceptable to KDHE. If foaming is expected to be excessive, then a potable water spray system shall be placed in the contactor head space.

- h) All gasketed openings into the contactor shall be properly sealed using welds or ozone resistant gaskets such as PTFE, expanded PTFE or chlorosulfonated polyethylene (Rakness, 2005).
- i) Multiple sampling taps shall be provided to enable sampling of each compartment's effluent water and determination of CT credit.
- j) A pressure/vacuum relief valve shall be provided in the contactor and piped to the destruction unit in a manner that will not damage the destruction unit.
- k) The contactor may work on either a countercurrent or cocurrent basis with respect to the ozone and water feeds. In either case, uniform distribution of ozone and adequate mixing of gas must be provided; and supplemental air may be needed to maintain the minimum flow needed to achieve these objectives, e.g., when the ozone concentration in the feed gas is high and the applied dosage is low.
- l) The contactor design shall facilitate cleaning and maintenance of the structure and internal piping, and drainage of the contactor. Each contactor compartment shall also be equipped with an access hatchway. Access hatchways must be gasketed, tightly sealed, and self draining. Hatchways (interior or exterior) located on top of the contactor must be curbed to an elevation of at least 4 inches (10.2 cm) above the deck. Hatches formed into the side walls of a contactor should be made self draining, i.e., with the ledges sloped to drain water away from the hatch.

2) Bubble Diffusers

- a) The depth of water in bubble diffuser contactors should be a minimum of 18 ft. (5.5 m) unless a smaller depth is justified by transfer efficiency considerations; and depths greater than 18 ft. (5.5 m) may be needed to achieve a transfer efficiency greater than 90 percent. The contactor should also have a minimum of 3 ft. (0.9 m) of freeboard to allow for foaming.

- b) Ozone shall be applied using porous-tube or dome diffusers spaced to achieve good distribution of gas bubbles over the floor area of the contactor. Gaskets shall be made of material suitable for use with the ozone concentration employed as gaskets are susceptible to deterioration (Rakness, 2005). Viton is in general considered to be a competitive alternative to expanded PTFE and chlorosulfonated polyethylene. Expanded Teflon is new to ozone service and is relatively expensive. Chlorosulfonated polyethylene performs well in applications where ozone concentrations are low, but performs poorly in applications where ozone concentrations are high. Aeration diffusers shall be fully serviceable for either cleaning or replacement.
- 3) Sidestream Dissolution Injection
- a) Sidestream dissolution injectors use pump/eductor units to mix a sidestream of water from the non-ozonated mainstream flow with highly concentrated ozone gas (10-12% by weight) and to then inject the resultant ozonated sidestream water solution into the non-ozonated mainstream flow upstream of the ozone contactor (Rakness, 2005).
 - b) At least two sidestream pump/eductor units must be provided, to provide a standby. Additional units may be advisable to minimize operating costs at turndown water flow rates.
 - c) Ozonated sidestream water may be degassed in a degassing vessel prior to injection into the mainstream flow or injected directly into the mainstream flow. Off-gas from the degas vessel or alternatively from the head space of the ozone contactor must be routed to the ozone destruct system for destruction.
 - d) Optimum ozone transfer efficiency in the sidestream water is achieved differently in injector-degas-vessel and injector-only systems. Temperature, pressure, ozone concentration, and gas-to-liquid ratios are critical to each. Optimal transfer efficiency should be > 90%. Typical gas-to-liquid ratios for sidestream injector/degas vessels and sidestream injector only feeds are 0.1 or lower and 0.3 to 0.7, respectively (Rakness, 2005). The type of sidestream dissolution system employed must be factored into the contactor design to account for differences in mass transfer efficiency.

- e) Injection into the mainstream flow shall ensure that the concentrated ozone solution is thoroughly mixed into the mainstream flow before it enters the contactor. Mixing-enhancement nozzle injectors are typically utilized.
 - f) The ozone generator must be protected from backflow of water or water vapor. A fail-to-close ball valve operated by a high pressure switch, a liquid trap and a check valve, in that order, should be included the ozone gas line. Outlet valves for non-operating ozone generators should be closed.
 - g) Flow of ozone to each contactor must be controlled.
 - h) Pressure gauges must be provided along gas and liquid piping to facilitate trouble shooting.
 - i) A degas vessel may be necessary where the DO level in the ozonated water or bubbles entering the ozone contactor must be kept to a minimum.
 - j) Alternatively, stripping oxygen from ozonated water by the introduction of clean, compressed air into the last compartment of the contactor to reduce DO may be considered.
 - k) Detention time in the degas vessel and sidestream piping must be taken into account in order to properly adjust the applied ozone dose to off-set ozone decay.
 - l) Capital and operating costs may differ for the injection-degas-vessel and direct-injection options.
- 4) Other Ozone Dissolution-Injection Contactors – Other contactors, such as those that utilize a sidestream venturi injector with downflow tube (J-tube), or a static mixer, may be approved by KDHE provided that adequate ozone transfer is achieved and the contact times and residuals required for disinfection can be met and verified.

e. OZONE DESTRUCT UNIT

- 1) A system for treating the final off-gas from each contactor must be provided in order to meet applicable safety and air quality standards. Acceptable systems include thermal destruction and thermal/catalytic destruction units.

- 2) In order to reduce the risk of fires, the use of units that operate at lower temperatures is encouraged, especially where high purity oxygen is the feed gas.
- 3) The maximum allowable ozone concentration in the destruct unit's discharge is 0.1 ppm (by volume) based on the maximum recommended limit for worker exposure for eight hours or more.
- 4) At least two units shall be provided which are each capable of handling the entire gas flow.
- 5) Exhaust blowers shall be provided in order to draw off-gas from the contactor into the destruct unit.
- 6) Catalysts must be protected from froth, moisture, and other impurities which may harm the catalyst. Demisters are typically used to provide this protection.
- 7) The catalyst and heating elements shall be located where they can easily be reached for maintenance.

f. CONTROL OF RESIDUAL OZONE AND HYDROGEN PEROXIDE

- 1) Since residual ozone decays rapidly, removal or quenching of residual ozone is often not necessary. However, when high dosages of ozone are employed (especially at lower pH values) or when water having a measurable ozone residual flows into an enclosed space (e.g., a filter building), it may be necessary to remove or quench the residual ozone to avoid exposing people to unsafe levels of off-gassing ozone. Options include: adding an additional contactor or a detention basin to provide sufficient time for the ozone to dissipate; increasing pH to accelerate ozone decay; air stripping (with the air vented to the ozone off-gas destruct unit); adding hydrogen peroxide to catalyze ozone decomposition (e.g., as part of an advanced oxidation process); and quenching the residual ozone with sodium bisulfite or calcium thiosulfate. Adequate safeguards must be in place to prevent overdosing of quenching agents, since any excess will interfere with subsequent disinfection processes.
- 2) If hydrogen peroxide is used in combination with ozone or UV radiation in an "advanced oxidation process" designed to remove organic contaminants, the residual hydrogen peroxide will exert a significant chlorine demand. Therefore, excess hydrogen peroxide must be quenched prior to chlorine addition (or the chlorinators must be adequately sized to meet the added demand associated with the

hydrogen peroxide). Overfeeding of a quenching agent such as sodium bisulfite or calcium thiosulfate will also exert a significant chlorine demand, so adequate safeguards (including appropriate analytical methods for process control) must be provided to ensure the integrity of subsequent disinfection processes.

- g. PIPING MATERIALS – Only low carbon 304L and 316L stainless steels shall be used for ozone service with 316L the preferred.

- h. JOINTS AND CONNECTIONS

- 1) Connections on piping used for ozone service are to be welded where possible; otherwise, flanged connections shall be used.
- 2) Connections with meters, valves, or other equipment are to be made with flanged joints with ozone resistant gaskets, such as PTFE or chlorosulfonated polyethylene. Screwed fittings shall not be used because of a tendency to leak.
- 3) A positive closing plug or butterfly valve plus a leak-proof check valve shall be provided in the piping between the generator and the contactor to prevent moisture reaching the generator.

- i. INSTRUMENTATION

- 1) Pressure gauges shall be provided at the discharge from the air compressor, at the inlet to the refrigeration dryers, at the inlet and outlet of the desiccant dryers, at the inlet to the ozone generators and contactors, and at the inlet to the ozone destruction unit.
- 2) Electric power meters should be provided for measuring the electric power supplied to the ozone generators. Each generator shall have a trip which shuts down the generator when the wattage exceeds a certain preset level.
- 3) Dew point monitors shall be provided for measuring the moisture of the feed gas from the desiccant dryers. Because it is critical to maintain the specified dew point, it is recommended that continuous recording charts be used for dew point monitoring which will allow for proper adjustment of the dryer cycle. Where there is potential for moisture entering the ozone generator from downstream of the unit or where moisture accumulation can occur in the generator during shutdown, the installation of post-generator dew point monitors should be considered.

- 4) Flow meters shall be provided for measuring inlet gas at the application point to each contactor. Additional recommended flow monitoring points include air flow from the desiccant dryers to each of the ozone generators and purge air flow to the desiccant dryers.
 - 5) Temperature gauges shall be provided for the inlet and outlet of the ozone cooling water and the inlet and outlet of the ozone generator feed gas, and, if necessary, for the inlet and outlet of the ozone power supply cooling water.
 - 6) Water flow meters shall be installed to monitor the flow of cooling water to the ozone generators and, if necessary, to the ozone power supply.
 - 7) Ozone monitors shall be installed to measure ozone concentrations in both the feed-gas and off-gas from the contactor and in the off-gas from the destruct unit. For disinfection systems, monitors shall also be provided for monitoring ozone residuals in the water. The number and location of ozone residual monitors shall be such that the amount of time that the water is in contact with the ozone residual can be determined.
 - 8) A minimum of one ambient ozone monitor shall be installed in the vicinity of the contactor and a minimum of one shall be installed in the vicinity of the generator. Ozone monitors shall also be installed in any areas where ozone gas may accumulate.
- j. ALARMS – The following alarm/shutdown systems should be considered at each installation.
- 1) Dew Point Alarm/Shutdown – This system should shut down the generator in the event the system dew point exceeds -76 °F (-60 °C).
 - 2) Ozone Generator Cooling Water Flow Alarm/Shutdown – This system should shut down the generator when cooling water flow decreases to the point that generator damage could occur.
 - 3) Ozone Power Supply Cooling Water Flow Alarm/Shutdown – This system should shut down the power supply when cooling water flow decreases to the point that damage could occur to the power supply.
 - 4) Ozone Generator Cooling Water Temperature Alarm/Shutdown – This system should shut down the generator if either the inlet or outlet cooling water exceeds a certain preset temperature.

- 5) Ozone Power Supply Cooling Water Temperature Alarm/Shutdown – This system should shut down the power supply if either the inlet or outlet cooling water exceeds a certain preset temperature.
- 6) Ozone Generator Inlet Feed-Gas Temperature Alarm/Shutdown – This system should shut down the generator if the feed-gas temperature is above a preset value.
- 7) Ozone Generator Inlet Feed-Gas Flow Alarm/Shutdown – This alarm should sound when the feed-gas flow to the generators is less than a preset value.
- 8) Ambient Ozone Concentration Alarm/Shutdown – The alarm should sound when the ozone level in the ambient air exceeds 0.1 ppm (by volume) or a lower value chosen by the water supplier. Ozone generator shutdown should occur when ambient ozone levels exceed 0.3 ppm (or a lower value) in either the vicinity of the ozone generator or in the vicinity of the contactor.
- 9) Ozone Destruct Temperature Alarm – The alarm should sound when temperature exceeds a preset value.

k. SAFETY

- 1) The maximum allowable ozone concentration in the air to which workers may be exposed must not exceed 0.1 ppm (by volume).
- 2) Noise levels resulting from the operating equipment of the ozonation system shall be controlled to within acceptable limits by special room construction and equipment isolation.
- 3) High voltage and high frequency electrical equipment must meet current fire and electrical codes.
- 4) Emergency exhaust fans must be provided in the rooms containing the ozone generators to remove ozone gas if leakage occurs. Self-contained breathing apparatuses should be located in hallways outside rooms subject to ozone hazards.
- 5) A portable purge air blower that will remove residual ozone in the contactor prior to entry for repair or maintenance should be provided.
- 6) A sign shall be posted indicating “No Smoking, Oxygen in Use” at all entrances to the treatment plant. In addition, no flammable or combustible materials shall be stored within an oxygen storage or

ozone generator area. Materials of concern include oil, grease, paper, PAC and GAC, organic solvents, petroleum products, and paint. Additional warning placards and/or other signage shall be posted as is deemed necessary.

- 7) The facility shall be properly located to ensure safe operation.

1. CONSTRUCTION CONSIDERATIONS

- 1) Prior to connecting the piping from the desiccant dryers to the ozone generators, the air compressors should be used to blow the dust out of the desiccant.
- 2) The contactor should be tested for leakage after sealing the exterior. This can be done by pressurizing the contactor and checking for pressure losses.
- 3) Connections on the ozone service line should be tested for leakage using the soap-test method prior to placing the ozone facility into service.

7. ULTRAVIOLET (UV) DISINFECTION – UV light may be used to treat surface waters (including GWUT) to achieve compliance with the disinfection requirements of the LT2ESWTR (40 CFR 141.700 et seq.) and to achieve inactivation of *Giardia lamblia* as part of complying with the log removal and/or inactivation requirements of the SWTR. Although it is relatively inefficient for virus inactivation, there may be circumstances under which it could be considered as a treatment to achieve at least a 4-log inactivation of viruses if required by the GWR (40 CFR 141.400 et seq.). It may also be used to provide supplemental disinfection beyond that required by State or Federal regulations.

In support of the LT2ESWTR, the USEPA has developed the *UV Disinfection Guidance Manual* (UVDGM) (USEPA, 2006a) which provides detailed technical information regarding the application of UV disinfection by PWSSs. This document focuses on surface water supplies, but much of the information presented also pertains to groundwater supplies. This document should be reviewed and KDHE should be consulted prior to submittal of a preliminary engineering report proposing installation of a UV disinfection system.

UV light can also be used alone or in combination with chemicals such as hydrogen peroxide to oxidize chemical contaminants (regulated or unregulated, and synthetic or naturally occurring). A decision to use such a process should be made only after its suitability for treating a potable water supply and its technical and economic feasibility have been adequately demonstrated, and after consultation with KDHE. For UV systems employing chemical addition, special validation protocols may be required for

disinfection credit. Some requirements described below (e.g., biodosimetry-based validation testing) are not applicable to UV systems for which no disinfection credit is claimed; but many of the considerations and requirements described below are applicable to such systems, and other site-, contaminant-, and process-specific requirements may apply. For systems employing a very high UV dose ($>200 \text{ mJ/cm}^2$) or using chemicals in conjunction with UV light, the engineer must satisfactorily demonstrate that the process does not introduce significant levels of chemical byproducts (including biodegradable organic matter) or chemical residuals into the water. Quenching of residual hydrogen peroxide may be necessary to control chlorine demand (Subsection 6.f).

The output of a UV lamp can vary significantly with temperature, but most lamps are mounted in quartz sleeves that provide insulation, allowing the lamps to reach an adequate temperature even when the water is very cold. Furthermore, UV lamp output is typically controlled to a specified level by a power supply linked to a UV sensor. Water temperature does not appear to influence UV disinfection at a given UV dose (fluence); but it may affect UV oxidation of chemical contaminants, and this possibility needs to be adequately addressed in the design of a UV oxidation system.

Since UV disinfection and UV oxidation are relatively new technologies for PWSSs, and since technological developments are occurring at a rapid pace, portions of Subsection A.5 of Chapter III may be applicable.

a. WATER QUALITY AND PRETREATMENT REQUIREMENTS

Particles (turbidity), chemical species that absorb UV light, and chemical constituents that foul lamp sleeves can significantly and adversely influence the effectiveness of UV disinfection. In properly pretreated water, the effects of these substances on UV disinfection can be adequately addressed by using UV intensity sensors and adjusting the output of the UV lamps as water quality fluctuates. Nevertheless, since experience with UV disinfection in Kansas is limited, KDHE will determine pre- and post-treatment requirements for UV disinfection on a case-by-case basis. The following water quality parameters are of particular concern:

- 1) Turbidity – The turbidity of the influent water must be controlled to less than 1 NTU. In surface water applications, UV disinfection must be preceded by filtration. Note that the UV dose requirements listed in Table 1.4 of the USEPA's *UV Disinfection Guidance Manual* (USEPA, 2006a) and LT2ESWTR (40 CFR 141.720(d)(1)) apply only to post-filter applications, in systems that filter under Subpart H, and to systems meeting filtration avoidance criteria, which are not applicable in Kansas.

For unfiltered groundwater supplies (excluding GWUI), a 5- μ m pre-filter shall be provided, as a minimum, ahead of each UV reactor if the peak turbidity exceeds 1 NTU. For low-turbidity groundwater supplies (not requiring a pre-filter), removable screens should be installed upstream of the UV reactors if it is possible that large debris might enter the system (e.g., due to failure of a well screen or pump impeller).

Particles, even those in filtered water, will accumulate on the surfaces of the lamp sleeves over time. Therefore, an appropriate means of cleaning the lamp sleeves must be provided.

- 2) UV Transmittance (UVT) And Total Organic Carbon (TOC) – UVT, a measure of the ability of UV light to pass through the water, is influenced by turbidity, natural organic matter (typically measured as TOC), color, iron and manganese, ozone, permanganate, and other chemicals that may be present in the water or added during treatment. The UVT of the influent water must be well characterized and controlled to a level that ensures that an adequate level of disinfection can be achieved at all times. Validation testing must be done with water having a UVT equal to or less than the water to be treated.
- 3) Iron (Fe) And Manganese (Mn) – Fe(III) strongly absorbs UV light, Fe and Mn can precipitate to form particles that block UV light, and Fe and Mn can form scale on the lamp sleeves. Fe and Mn must be below the secondary MCLs (0.3 and 0.05 mg/L, respectively) prior to UV application.
- 4) Scale-Forming Constituents – Scale formation on the lamp sleeves reduces the amount of UV light entering the water column. Scales promoted by an increase in water temperature are of particular concern, since the lamp sleeves are warmed by the lamps. Scale compounds of concern include: CaCO_3 , Mg(OH)_2 , CaSO_4 , Al(OH)_3 , Fe(OH)_3 , FeCO_3 , BaSO_4 , oxides of Mn, SiO_2 , and various silicates, phosphates, and sulfides. The potential of water to form scale on the lamp sleeves must be adequately evaluated and, if necessary, controlled. This is typically accomplished by performing solubility calculations (based on adequate water quality data and taking into consideration the effects of temperature as well as chemical species added to or removed from the water by treatment prior to UV disinfection) and/or conducting pilot-, demonstration-, or full-scale testing on the water to be treated or one similar in quality with respect to scaling potential.
- 5) Ozone – Ozone strongly absorbs UV light, but also acts synergistically in concert with UV light to promote disinfection and oxidation. If residual ozone may be present as the water enters the UV reactor, this

must be taken into consideration in the design and operation of the system and in validation testing.

b. DESIGN CONSIDERATIONS AND REQUIREMENTS

- 1) Reactor Number, Configuration, And Layout – The number of UV reactors provided, including critical system components, shall be sufficient to assure a continuous water supply when one unit is out of service. Closed-channel reactors mounted in parallel shall be used, unless circumstances merit consideration of other configurations. The proposed layout should include reactor dimensions, inlet and outlet configurations, any devices used to modify flow upstream or downstream of the reactors, individual flow meters, individual vent valves, and the locations of control panels, electrical panels, off-line cleaning systems, and other appurtenances. When flow through a series of UV reactors operating in parallel is not individually controlled, all upstream and downstream piping arrangements shall ensure equal flow through all of the UV reactors. Where validation is conducted at an off-site testing facility, the UV reactor/piping layout shall be designed based on the validated inlet and outlet conditions as outlined in the UV reactor's validation report. The inlet and outlet hydraulics shall be designed according to manufacturer recommendations and to accommodate any site-specific constraints where on-site validation or custom off-site validation is planned. Additional discussion of UV reactor and piping layouts can be found in the USEPA's *UV Disinfection Guidance Manual* (USEPA, 2006a).
- 2) Lamp Type, Number, Arrangement, And Orientation – The lamp type, manufacturer, performance characteristics, and emission spectrum shall be specified. Low-pressure (LP), low-pressure high-output (LPHO), and medium-pressure (MP) lamps are typically used in PWS applications. A proposal to use MP lamps must include a description (graphical or numerical) of the spectral variations that occur as the lamps age, along with technical documentation (from the manufacturer or an independent source) regarding the impact of spectral shifts on germicidal effectiveness and the safety factors used to address such shifts. Other types of ultraviolet lamps will be considered on a case-by-case basis. Lamp orientation may be parallel, perpendicular, or diagonal to the flow or ground. The number of lamps in each reactor, including their arrangement and orientation, shall be specified.
- 3) UV Dose Requirements – The UV dose (or fluence, typically expressed in units of millijoules per square centimeter, mJ/cm^2) required to achieve a specified level of inactivation depends on the nature of the organism, the characteristics of the reactor, and water quality.

The UV doses required to achieve various levels of inactivation of *Cryptosporidium*, *Giardia lamblia*, and viruses (adenovirus) have been tabulated by the USEPA in the UVDGM (USEPA, 2006a) (40 CFR 141.720(d)(1)). These UV doses are applicable only to post-filter applications of UV in filtered systems for UV light at a wavelength of 254 nm as produced by a low pressure mercury vapor lamp. As outlined in the USEPA's *UV Disinfection Guidance Manual* (USEPA, 2006a), the validated dose is determined by applying a validation factor to these values to quantitatively account for various key uncertainties such as reactor hydraulics, measurement uncertainties, and variations among lamps.

The UV dose effectively delivered to the water by a full-scale reactor can not be directly measured, but is determined (during validation testing) by comparing the inactivation of challenge microorganisms achieved by the reactor to the organisms' dose-response curve obtained in a collimated-beam test (USEPA, 2006a). UV doses thus determined are referred to as "reduction equivalent doses" (REDs) (USEPA, 2006a).

- 4) Hydraulic Considerations – The flow rate through each reactor must be limited (reliably controlled) to the maximum flow rate for which reactor performance has been validated; and the hydraulic characteristics of the inlet and outlet of each reactor must be identical to (or demonstrably more conservative than) those used during reactor validation testing.

Since UV reactors must flow full during operation (to avoid lamp damage and for proper flow distribution), they should be placed below the hydraulic grade line. Air release valves or combination air/vacuum relief valves may be needed to prevent air pockets and negative pressures; and water-level sensors may be needed, in some systems, to warn the operator that the reactor is not full.

Reactor operating pressure must be limited to the maximum for which the reactors are designed; and pressure surges (including negative pressures) and vibrations (e.g., from pumps and motors) sufficient to damage the lamps, lamp sleeves, or other components must be eliminated.

Any product water bypassing UV disinfection must be piped to waste (or a suitable recovery basin) unless provision is made for another means of providing the required level of disinfection before the water enters the distribution system.

Drains (designed to allow rapid and complete draining) and isolation valves must be provided to facilitate inspection, maintenance and repair activities. A clean (potable) water supply should be readily available for use in cleaning and maintenance activities.

- 5) Power Supply – The potential for power fluctuations to shut down or dim the UV lamps, or to damage them by causing excessive lamp on/off cycling, must be evaluated and, if necessary, reduced, e.g., by installing such devices as alarms, automatic shut-off valves that direct inadequately disinfected water to waste, and uninterruptible power supply (UPS) units. Although power quality problems may not cause a PWSS to produce off-spec water, they can increase costs, reduce operational flexibility, and adversely affect lamp life and lamp operation (Cotton *et al.*, 2005).

All UV-system electrical and electronic components should be UL approved and, since they could potentially be exposed to high-pressure water, ground-fault circuit interruption (GFCI) circuitry is required and a water-proof enclosure (NEMA 4 or better) is recommended. Ballasts must be properly mated with the lamps being used, adequately ventilated, and thermally protected.

Careful attention should be paid to the electrical wiring of the UV systems to avoid electrical hazards, component failures, and fires. Wiring should be properly sized and, where appropriate, wire coverings should be UV resistant.

Reactor housings shall be constructed of stainless steel (314 or 316L). All components of the system exposed to UV light shall be UV resistant, and components that come into contact with the water shall not impart toxic constituents into the water (either by leaching or as a result of exposure to UV light).

- 6) Instrumentation And Control – The instrumentation and control system must be designed to monitor reactor performance, flow rate, and influent water quality; to prevent damage to the reactor; to meet the O&M and monitoring requirements described below; and to prevent inadequately disinfected water from entering the distribution system. The instrumentation and control system should include an appropriate level of redundancy.

Instrumentation, including appropriate sensors and alarms, shall be provided to monitor the following in each reactor: flow rate, liquid level (if it is possible for air to enter the reactor when it is in operation), power status (on/off), reactor power setting (if applicable), UV intensity

(or dose), lamp temperature, cumulative number of on/off cycles, and, for each lamp, lamp status (on/off) and cumulative lamp operating time in hours. (Monitoring frequency requirements are described below.) The cumulative operating time and number of on/off cycles for each lamp must be recorded on non-resettable counters. Provision should also be made to monitor cumulative power consumption to help assign costs and to assess future energy conservation measures or the economic feasibility of alternative systems.

Suitable instrumentation must be provided to enable the operator to reliably monitor influent water quality. See Subsection 7.a, Water Quality and Pretreatment Requirements, above, and Table V-3, below, which summarizes monitoring and reporting requirements. Sampling frequency and the specific constituents monitored will depend on regulatory requirements and the nature and quality of the source water. UVT must be continuously monitored if this parameter is used for UV dose control. Sampling taps suitable for collecting representative influent and effluent samples must be provided.

Each reactor must have a UV intensity sensor system (including one or more stable, reliable, and appropriately located UV intensity sensors) suitably integrated into the control system and included in validation testing. During validation testing and plant start-up, each UV intensity sensor must be individually calibrated to an absolute standard. Appropriate documentation (obtained from the manufacturer or an independent source) must be provided to: verify that the sensor characteristics (measurement range, angular response, spectral response, linearity, and stability) are suitable for monitoring and controlling the UV dose for disinfection credit; describe the measurement standards and the uncertainty of each measurement; describe the quality control and quality assurance procedures used to calibrate the sensors to NIST-traceable standards; and demonstrate that the sensors reliably meet specifications over an extended period of time.

Sensor location must be compatible with the UV dose monitoring approach and sensors must monitor the sections of the lamps that experience the greatest decrease in UV output with aging (USEPA, 2006a). If each lamp is not fitted with an individual UV intensity sensor, the control system and operating procedures must be designed to ensure an adequate level of disinfection when unmonitored lamps burn out or produce less UV light than those lamps which are being monitored. Sensors whose readings are sensitive to their orientation must be oriented to the point of minimum intensity or keyed such that

their orientation is fixed. The lamp monitoring strategy must ensure compliance with regulatory requirements for UV dose.

The control system must be fail-safe, i.e., in the event of a power outage, inadequate UV intensity or dose, exceedance of the maximum flow rate or of an influent water quality limit, or major system malfunction, an audible alarm shall sound and the water system shall automatically shut down (or the water shall automatically flow to waste) until the problem is corrected, thereby ensuring that inadequately disinfected water does not reach a consumer. (Use of a backup disinfection system able to meet all applicable disinfection requirements will be considered in lieu of an automatic shutdown or pipe-to-waste approach.) Alarms must also be provided to indicate: lamp or ballast failure, high reactor temperature, low flow, production of off-specification water, and (if applicable) wiper failure.

LT2ESWTR requires validation of UV reactors (40 CFR 141.720(d)). The results of the validation testing establish the conditions under which UV reactors must be operated to ensure the required UV dose delivery and to ensure that at least 95% of the water delivered to the public during each month is treated by UV reactors operating within their validated limits (40 CFR 141.720(d)(3))(USEPA, 2006a). Proposals that would allow up to 5% of the treated water delivered to the public during each calendar month to be "off specification" will be considered if safeguards that adequately protect public health are included. Factors KDHE will consider in evaluating such proposals include: annual *Cryptosporidium* risk (with the goal of the LT2ESWTR being less than 1 in 10,000); raw water quality; other disinfection processes used and the disinfection credit they are awarded; and the conditions under which off-specification water will be produced, i.e., how far outside the validation conditions the UV reactors will be operated before production ceases.

The control system must be designed to accommodate the start-up and shutdown requirements of the lamps without compromising the quality of the finished water or damaging the lamps. This may require installation of a bypass-to-waste line to carry off-specification water diverted by automatically operated diversion valves. The control system should be designed to avoid excessive on/off cycling of the lamps and overheating of the lamps, both of which reduce lamp life.

- 7) Operation And Maintenance (O&M) – O&M procedures, including those for system start-up and shutdown and for calibrating devices used to make critical measurements, such as UV dose (fluence), flow rate, UVT, and temperature (if applicable) must be developed based on the

manufacturer's recommendations and submitted in writing. The operating procedures should include contingency plans describing the actions to be taken following lamp breakage, major alarms (e.g., inadequate UV dose), failure of upstream processes, and power supply interruptions. System start-up plans must include a performance test as described in the USEPA's *UV Disinfection Guidance Manual* (USEPA, 2006a). The calibration of each UV intensity sensor must be checked at least monthly against a reference sensor, and a sensor whose readings do not fall within acceptable limits (USEPA, 2006a) must be replaced with another calibrated sensor. The reference sensor must be calibrated at least once annually at a qualified facility; and, if it is found to be out of calibration, the calibration interval must be shortened.

For routine operation, the intensity of each lamp shall be checked bimonthly and the lowest intensity lamp in a given reactor shall be placed in the position closest to the UV intensity sensor if one sensor monitors multiple lamps.

If UVT is used to control the UV dose, the calibration of the UVT monitor must be checked at least weekly unless data are available to support a less frequent calibration interval.

UV reactors must be designed to accommodate visual inspections, as well as physical inspection of internal surfaces, and to provide reasonably convenient access to lamps, lamp sleeves, sensors, sensor lenses or windows, lamp-wiper assemblies, and other system components to facilitate cleaning, calibration, repair, and replacement activities.

Appropriate means for routine in-place cleaning of the lamp-sleeve surfaces must be provided. The cleaning method(s) used may be physical, mechanical, or chemical, and may be done on-line or off-line; but the method or combination of methods used should be demonstrably effective. If lamp sleeves are to be cleaned chemically, the chemicals used must be approved for use in drinking water applications (KAR 28-15-18(h)) and provisions must be made to ensure that they do not contaminate the finished water (including cross-connection control) and that they are properly disposed of. UV reactors that are taken out of service for an extended period of time should be drained and stored in a dry condition.

The useful life of lamps, lamp sleeves, ballasts, UV intensity sensors, and other system components that will eventually require replacement should be considered in estimating operating costs (Subsection A.7 of Chapter III). The useful life of some components may be influenced by

raw water quality and the frequency and effectiveness of cleaning. Other factors to consider include experience with the same or similar components (especially when treating the same or similar water) and the supplier's performance guarantees.

Adequate provisions (procedures, equipment, and protective devices) shall be made for protecting the safety of operating staff and visitors from hazards, including those associated with UV light exposure, electricity, burns from lamps or equipment, broken lamps, and mercury exposure.

If the UV lamps contain mercury, an assessment of the vulnerability of the system (including storage) to lamp breakage and mercury release must be provided, and emergency response plans (for off-line and on-line breakage) and a waste disposal plan must be submitted for approval.

A recommended spare-parts inventory that reasonably enhances the reliability of the UV disinfection system should be included in the operating procedure. Replacement lamps must be the same as those used in validation testing. Use of alternative lamps must be approved by KDHE and may require reactor re-validation.

Adequate space must be provided for all O&M activities.

Operator training shall be provided prior to system start-up.

- 8) Monitoring and Reporting Requirements – The LT2ESWTR requires utilities to monitor their reactors to demonstrate that they are operating within the range of conditions that were validated for the required UV dose (40 CFR 141.720(d)). At a minimum, utilities must monitor each reactor for flow rate, reactor status (on/off), lamp status (on/off), UV intensity (or dose), liquid level (if applicable), reactor power (if applicable), and selected measures of influent water quality where applicable. Monitoring and reporting of other parameters in addition to the above may also be required by the State at its discretion.

UVT must also be continuously measured where it is used in a dose control strategy. Systems must “regularly check the calibration of UV intensity sensors in accordance with a protocol provided by the manufacturer and approved by the State” (USEPA, 2006a).

The LT2ESWTR also requires “routine (i.e., monthly) reporting of the volume of water entering the distribution system that was not treated by UV reactors operating under validated conditions” (USEPA, 2006a).

UV systems used for disinfection credit must be continuously monitored for flow rate, reactor status (on/off), UV intensity or dose, cumulative number of reactor on/off cycles, water level (if applicable), reactor power setting (if applicable), lamp status, and cumulative lamp operating time. UVT must be continuously monitored if used for UV dose control; otherwise, it must be monitored at least weekly, and more often if necessary to ensure that the reactor is operating within the range of its validated operating conditions.

The following information must be reported monthly to KDHE: peak daily flow rate, maximum daily or weekly UVT, minimum daily UV intensity or dose, cumulative number of reactor on/off cycles, the percentage of treated water produced with the UV system operating outside its validated operating conditions, daily lamp status, monthly total operating time for each lamp, the date of each major alarm or unplanned system shutdown and its cause, and the date of each lamp replacement, sensor calibration, off-line chemical cleaning, and (where applicable) pre-filter replacement. Additional water quality monitoring may be required by KDHE, especially during system start-up. If so, the data must also be included in the monthly report to KDHE.

The minimum monitoring, recording, and reporting frequencies required and recommended by KDHE for parameters associated with UV disinfection are summarized in Table V-3. KDHE shall have access to both the UV disinfection system and the records associated with it.

- c. **REACTOR VALIDATION** – The LT2ESWTR requires use of validated UV reactors for inactivation credit (40 CFR 141.720(d)) and reporting of validation test results (40 CFR 141.721). Recommended procedures are described in the UVDGM (USEPA, 2006a). Current procedures are based on biosimetry; but more accurate procedures (e.g., procedures based on actinometry) may become available and, if so, proposals to use improved methods will be considered. Specific concerns and requirements pertaining to validation of reactors used in Kansas are as follows:

- 1) Validation requirement – Each reactor design used for disinfection must undergo biosimetry-based validation testing prior to being approved for use. Validation testing may be done off-site or on-site, but scale up is not acceptable. A reactor used to obtain disinfection credit must be operated within the range of conditions (including flow rate, UV intensity or dose, power setting, UVT, and lamp status) for which it has been validated. Plans for on-site validation testing should be submitted to KDHE for approval prior to testing.

Validation is not strictly required for applications where disinfection is not required, i.e., where the disinfection credit associated with the UV system is not needed (and will not be claimed) to meet applicable disinfection requirements. However, it is recommended that a validated reactor design be used to facilitate compliance with future changes in treatment requirements. When a UV system is initially installed for reasons other than disinfection credit, but at a later date is proposed for such a purpose, the UV system as installed will be evaluated within the regulatory framework that exists at the time disinfection credit is requested.

- 2) Third-party oversight – Third-party oversight is required to ensure that validation testing and data analyses are conducted in a technically sound manner and without real or perceived conflicts of interest. Validation testing should be overseen by a registered professional engineer who is both independent of the manufacturer and experienced in testing and evaluating UV reactors. KDHE will not require that the engineer overseeing the validation testing be registered in Kansas; however, a detailed report regarding the validation test and its results must be submitted with the engineer's report or with the plans and specifications, which must bear the seal of a professional engineer registered in the State of Kansas, thereby verifying the adequacy of the testing protocol and data analysis. Experts should be consulted if the engineer has limited experience in one or more pertinent areas (e.g., lamp physics, optics, hydraulics, microbiology, or electronics).
- 3) Test organism – Validation testing must be conducted with a test organism that is at least as resistant as the pathogens the system is designed to inactivate (if feasible) and whose dose-response characteristics have been quantified using a LP mercury-vapor lamp.
- 4) Lamp aging – Validation testing must take into account the effects of lamp aging, including reduced intensity, any spectral shifts that occur, blackening of the ends, and changes in intensity along the length of the lamps.
- 5) Other factors – Validation testing must also take into account uncertainties in measurements made using on-line sensors, the UV dose distribution associated with the velocity profile through the reactor, failure of the UV lamps or other critical system components, and inlet and outlet piping or channel configurations.
- 6) Revalidation – A reactor must be re-validated when any design or operational change is made that may affect its UV dose delivery characteristics. At this time, KDHE does not plan to approve any

alternative approaches, i.e., approaches not adopted by the UVDGM, e.g., use of CFD models or microspheres coated with a UV sensitive dye.

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**TABLE V-3 MINIMUM MONITORING, RECORDING AND REPORTING FREQUENCIES REQUIRED AND RECOMMENDED
BY KDHE FOR PARAMETERS ASSOCIATED WITH EACH UV REACTOR USED TO OBTAIN DISINFECTION CREDIT¹**

Parameter	Monitoring Frequency	Recording Frequency	Include in Monthly Report ²	Notes
Flow Rate	Continuous	Every 4 hours	Max. Day & Mo. Avg.	Must be within validated range
Lamp Status (On/Off)	Continuous	Every 4 hours	Only if Off	Must be energized when water flowing
Reactor Power Setting	Continuous	Every 4 hours	Min. Day & Mo. Avg.	If applicable (must be in validated range)
UV Intensity	Continuous	Every 4 hours	Min. Day & Mo. Avg.	Must exceed validated set point
Calculated UV Dose	Continuous	Every 4 hours	Min. Day & Mo. Avg.	Only if used for control purposes
UVT	Continuous	Every 4 hours	Min. Day & Mo. Avg.	Daily if not used for control purposes
Volume Treated	Daily	Daily	Monthly Total	
Volume Off-Spec	Continuous	Each Event	Events & Mo. Totals	Must be < 5% of volume treated
UV Sensor Calibration	Monthly	Monthly	All Results/Actions	Increase frequency if necessary
UVT Sensor Calibration	Weekly	Weekly	All Results/Actions	Increase frequency if necessary
Flow Meter Calibration	Monthly	Monthly	All Results/Actions	Increase frequency if necessary
Cum. Lamp On/Off Cycles	Continuous	Weekly	No	Use for O&M planning
Cum. Lamp On Hours	Continuous	Weekly	No	Use for O&M planning
Lamp Age	Monthly	Monthly	No	Use for O&M planning
Lamp Intensity	Bimonthly	Bimonthly	No	Locate lowest-intensity lamp next to the sensor
UV Sensor Age	Monthly	Monthly	No	Use for O&M planning
Ballast Age	Monthly	Monthly	No	Use for O&M planning
Sleeve Age	Monthly	Monthly	No	Use for O&M planning
Power Draw	Continuous	Every 4 hours	No	Use to assess energy use
Water Temperature	Continuous	Daily Max	No	Equipment limit not to be exceeded.
Reactor Water Level	Continuous	Every 4 hours	No	If applicable (to prevent lamp damage)
Influent Turbidity	Hourly	Hourly	Daily Average	Daily avg. must be ≤ 1 NTU
pH, Alk., Hardness, Fe & Mn	Weekly	Weekly	Monthly Average	Reduce in absence of fouling
Date of Last Chemical Cleaning	Monthly	Monthly	No	Use for O&M Planning

Notes:

1. Required frequencies and reporting information are shown in bold.
2. The monthly report must also include the date and cause of each major alarm, unplanned shutdown, and off-spec water event.

N. TASTE AND ODOR CONTROL

1. REQUIREMENT – All surface water supplies may have periodic taste and odor problems and means for their prevention and control should be provided. Attention should be given to these taste and odor problems in the management of the watershed, in the design of the treatment plant, and on the basis of past experience with the supply. Plants treating waters known to have taste and odor problems should be provided with equipment that allows several of the available control processes to be used so that the operator will have maximum flexibility in the plant's operation. Also, a pilot or in-plant study may be necessary to determine the best way to effectively deal with a severe taste and odor problem or to demonstrate the effectiveness of a proposed treatment technique. Selection of treatment processes used for taste and odor control, as well as their design basis, must be justified by the designer.
2. CHLORINE AND CHLORINE DIOXIDE – Historically, prechlorination has been used for controlling certain types of taste and odor problems. However, restrictions on DBPs often preclude this option. Chlorine dioxide is effective for treating certain types of taste and odor problems; but chlorine dioxide and its primary byproduct (chlorite) may need to be removed to ensure compliance with the MRDL for chlorine dioxide and the MCL for chlorite, or to prevent regeneration and volatilization of chlorine dioxide in the distribution system. It is also important to note that adding an oxidant (not only chlorine or chlorine dioxide, but also potassium permanganate or ozone) prior to clarification can exacerbate a taste and odor problem by lysing cells and releasing an additional amount of the offending chemical(s) into solution.
3. HYDROGEN SULFIDE REMOVAL – Hydrogen sulfide has a threshold odor concentration of less than 0.0001 mg/L (Cohn *et al.*, 1999) and at concentrations greater than 0.1 mg/L it can impart a very offensive odor to drinking water. Treatment methods commonly used to remove hydrogen sulfide include oxidation (using chlorine or other oxidants), aeration or air stripping (when more than traces of hydrogen sulfide are present), and filtration (to remove sulfur particles formed by the incomplete oxidation of hydrogen sulfide).
 - a. OXIDATION USING FREE CHLORINE – Chlorine reacts with hydrogen sulfide to form sulfate, but polysulfides and particles of elemental sulfur are also formed. These byproducts may be difficult to remove, may also contribute to taste and odor problems, and can react in the distribution system to create “black water” problems. If only traces of hydrogen sulfide are present (i.e., less than 0.3 mg/L) and a slight increase in finished water turbidity can be tolerated, plain chlorination may suffice. Higher concentrations can be effectively treated using aeration (to add oxygen to the water to impede reversion of sulfur and polysulfides to sulfide) or air stripping (to also remove a portion of the hydrogen sulfide, thereby reducing chlorine demand and minimizing formation of sulfurous byproducts),

followed by chlorine addition, a contact basin (to provide at least 2 hours detention time for chemical reactions and particle growth) and then filtration (to remove sulfur particles, as well as any particulate contaminants introduced by aeration or air stripping). White (1999) notes that colloidal sulfur and polysulfides can also be treated by adding sulfite to convert them to thiosulfate and then adding more chlorine to convert the thiosulfate to sulfate; but this treatment sequence will be considered as a new technology (Subsection A.5 of Chapter III). White also notes that polysulfide problems do not occur in lime softened water, presumably because sulfate formation is favored in the high-pH environment associated with lime softening.

- b. **OXIDATION USING OTHER OXIDANTS** – Other oxidants known to be effective for oxidizing hydrogen sulfide include ozone, potassium permanganate, hydrogen peroxide, and chlorine dioxide. Each of these oxidants can oxidize hydrogen sulfide to elemental sulfur and polysulfides, but an adequate dosage of chlorine dioxide (Gates, 1998) or ozone can carry the reaction to completion, leaving only sulfate as a byproduct. When chlorine dioxide is used, care must be taken to comply with the MCL for chlorite; and ozone can produce increased concentrations of bromate and biodegradable organic matter. Hydrogen peroxide reacts relatively slowly with hydrogen sulfide, so an adequate detention time must be provided; and it also exerts a significant chlorine demand, so careful control of the process is required to avoid overtaxing the disinfection process. Potassium permanganate reacts rapidly with hydrogen sulfide, but the reaction is typically incomplete and filtration must be provided to remove both elemental sulfur and manganese dioxide particles. Since hydrogen sulfide exerts a large oxidant demand, regardless of the oxidant used, air stripping should be considered when dealing with high concentrations of hydrogen sulfide. See Section M and Chapter IX for additional information regarding the design of facilities for feeding chemical oxidants.
- c. **AERATION AND AIR STRIPPING** – Forced draft air stripping should be considered for hydrogen sulfide concentrations exceeding 0.6 mg/L, and packed-tower air stripping for concentrations of 3 mg/L and higher (Section P). Air stripping can be used to reduce the concentration of hydrogen sulfide to a low enough level that the residual hydrogen sulfide can be readily removed by oxidation. Air stripping of hydrogen sulfide may require pH suppression, since above a pH of 7 more than half of the hydrogen sulfide will be present in ionized (non-strippable) form; and it may also require off-gas treatment to control odor. Aerators and air strippers introduce oxygen into the water, which stimulates the growth of sulfur oxidizing bacteria when a biocide is not present. These bacteria are in many cases responsible for a substantial amount of the hydrogen sulfide removal attributed to “aeration” and they are beneficial in that they reduce the oxidant demand associated with hydrogen sulfide and accumulate sulfur in forms that are easier to settle and

filter than the sulfur particles produced by chemical oxidation. However, these bacteria also contribute to increased turbidity and can pose other operational challenges; thus, if present, they must be properly managed.

- d. **FILTRATION** – Filtration may be needed following chemical oxidation or aeration to control turbidity by removing sulfur particles or sulfur oxidizing bacteria, respectively. Filtration is required following permanganate addition, to remove manganese dioxide solids (Section J).
 - e. **BENCH AND PILOT STUDIES** – KDHE may require bench and/or pilot studies to verify the adequacy of the proposed treatment system, especially when experience with the proposed system is limited. Treatment processes other than those listed above (e.g., biological processes and catalytic adsorption) will be considered as new technologies (Subsection A.5 of Chapter III).
4. **POWDERED ACTIVATED CARBON (PAC)** – PAC is commonly added as part of controlling taste and odor problems associated with naturally occurring organic contaminants, especially those produced by algae and bacteria. Tastes and odors can arise from a single compound, but they can also arise from a combination of compounds that may be difficult to quantify but is nonetheless amenable to removal using PAC. PAC is commonly added to control taste and odor problems associated with seasonal events such as algal blooms, reservoir turnover, or heavy rains.
- a. **POINT OF ADDITION** – In selecting the point of PAC addition, consideration should be given to the following:
 - 1) Selecting the primary point of PAC addition to maximize PAC contact time; for taste and odor, however, having more than one point of addition to provide flexibility is preferred.
 - 2) Enhancing contact between the PAC and the water being treated by providing adequate mixing.
 - 3) Allowing sufficient contact time for adsorption of the contaminant(s) of concern. The required contact time is a function of the characteristics and concentration of the molecule(s) to be adsorbed, the dosage of the PAC, and the presence of any competing organics in the water.
 - 4) Minimizing interference of other treatment chemicals with the adsorption process. Activated carbon will chemically reduce oxidants such as chlorine, chlorine dioxide, ozone, and permanganate. Such reactions not only increase oxidant/disinfectant demand, but in some cases can also reduce the adsorptive capacity of the carbon for the

compound(s) of interest. The chemicals used for coagulation and lime softening can form coatings on PAC particles, reducing their ability to adsorb contaminants; however, coagulation and softening can also enhance removal of trace contaminants by removing naturally occurring organic matter that would otherwise compete for adsorption sites. Jar tests may be needed to determine the optimum point of addition.

- 5) Providing flexibility regarding the point of addition of PAC. Generally recommended points of PAC addition include the pipeline carrying raw water to the plant and the inlets to the rapid mix basin, flocculation, and sedimentation basins. When PAC remains in the settled water or is applied after sedimentation, prior to filtration, it is important to recognize that the PAC in the water or captured on the filters may react with chlorine or other oxidants. Thus, an increased dosage of chlorine may be required to maintain an adequate residual in the treated water and additional steps (e.g., chlorine addition to the backwash water) may be needed to control bacterial growths in the filters. Furthermore, the PAC dosage must be carefully controlled lest PAC carried over to the filters breaks through, causing erroneously low filtered-water turbidity readings and contaminating the treated water with black particles.
- b. RATE OF APPLICATION – The required dosage of PAC depends upon the taste and odor problem involved; but the upper limit is usually controlled by the amount of carryover that can be handled by the filters. Provisions should generally be made for adding 1 to 40 mg/L, but higher doses may be needed to address a severe taste and odor problem.
- c. METHOD OF APPLICATION – PAC should be added as a slurry to the water being treated. This approach requires mixing to uniformly disperse the carbon throughout the stock slurry. A dry feeder is typically used to prepare the slurry, though the PAC can also be slurried upon delivery; and an agitator keeps the PAC in suspension. The PAC concentration in the slurry should not exceed 0.5 to 1.0 lb/gal (60 to 120 g/L) to reduce settling and to maintain fluid conditions suitable for handling. Once the PAC is wetted, the slurry can be pumped into feed lines with periodic water flushing or transferred by eduction to prevent caking. Slurry storage, sized to accommodate delivery of truck or railcar quantities, is recommended for larger PWSSs. Continuous agitation is necessary to keep the PAC from depositing in the slurry storage tank and to aid in wetting the PAC upon receipt.

Provisions shall be made to minimize dust. A separate room shall be provided for a carbon feed installation. PAC shall be handled as a potentially

combustible material and carbon feeder rooms should be equipped with explosion-proof electrical outlets, lights, and motors.

PAC, in dry or slurried form, adsorbs oxygen from the air. Therefore, enclosed spaces where PAC is stored must be adequately ventilated and equipped with oxygen monitors, alarms, and other appropriate safety features to avoid an oxygen deficient environment. See Chapter IX for additional information regarding PAC storage and handling.

5. GRANULAR ACTIVATED CARBON (GAC) – See Section J on Filtration and Section Q on Adsorption with GAC for related design criteria.
6. POTASSIUM PERMANGANATE – Application of potassium permanganate may be considered provided that permanganate and its end product, manganese dioxide, do not impart a visible color to the finished water in the clearwell and compliance with the SMCL for Mn (0.05 mg/L) is maintained. A residual Mn concentration of 0.02 mg/L or less entering the distribution system is strongly recommended. The application point should be at the rapid mix basin in conjunction with coagulant addition or upstream, e.g., at the raw water intake or before or after presedimentation, depending on water quality, the nature of the compound(s) responsible for the taste and odor problem, and the treatment provided.
7. OZONE – Ozonation can be used as a means of taste and odor control. Adequate dosage and contact time must be provided to complete the chemical reactions involved. Ozone is generally more feasible when treating water with severe taste and odor problems. See Section M on Disinfection for detailed information on the design of ozonation systems.
8. TASTE AND ODOR ARISING IN THE DISTRIBUTION SYSTEM – Taste and odor problems can develop after treatment in the distribution system as a result of chemical and/or biological reactions, e.g., corrosion, nitrification, sulfate reduction, and unmasking of taste- and odor-causing compounds as residual chlorine decays. Methods to alleviate such problems include maintaining a suitable free or combined chlorine residual, periodic maintenance of distribution system mains (e.g., by flushing, pigging, or shock chlorinating), and removing or oxidizing contaminants (at the treatment plant) that can be masked by residual chlorine.
9. OTHER METHODS – The decision to use any other methods of taste and odor control should be made only after careful laboratory and/or pilot-plant tests, and consultation with KDHE.

O. IRON AND MANGANESE REMOVAL

The control of iron and manganese usually requires the selection of one or more treatment processes designed specifically for this purpose, taking into account specific local conditions

as determined by engineering investigations. It may be necessary to conduct laboratory tests or operate a pilot plant to facilitate these investigations. Historically, pilot studies have been conducted to confirm design parameters and provide the basis for developing design parameters based on local conditions.

The filtration step of any iron/manganese removal processes shall be designed to treat the maximum day demand (or design rate) and to meet the effluent treatment objectives specified in the design at an individual filter loading rate of no more than 5 gpm/ft² (204 L/min-m²). A minimum of two filters is required. When only two filters are to be provided, each filter should be capable of treating the maximum daily demand. When more than two filters are to be provided, the filters should be capable of treating the maximum daily demand with one filter removed from service. In all cases, the filter design shall include provisions to facilitate complete isolation of individual filters from other filters. KDHE will on a case-by-case basis consider granting requests to operate at higher individual filter loading rates if the results of on-site pilot testing adequately support such requests. It is recommended that KDHE be given the opportunity to review and comment on the pilot testing protocol prior to beginning the testing. KDHE must approve the proposed treatment scheme.

1. REMOVAL BY OXIDATION, DETENTION, AND FILTRATION

- a. DESCRIPTION OF REMOVAL PROCESS – This approach involves oxidizing iron and manganese to insoluble forms, providing time for the precipitated iron and manganese to form particles, and then filtering out the particles. Ferrous iron, Fe²⁺, is oxidized to ferric ion, Fe³⁺, and precipitated as ferric hydroxide, Fe(OH)₃; and manganous manganese, Mn²⁺, is oxidized to tetravalent manganese, Mn⁴⁺, and precipitated as manganese dioxide, MnO₂. Oxidation may be accomplished using oxygen, provided by gravity, forced or induced draft aerators, or using free chlorine (but not combined chlorine), chlorine dioxide, ozone, or potassium permanganate.
- b. DETENTION TIME – Sufficient detention time must be provided, prior to filtration, using a separate detention basin, sedimentation basin, or solids contact reactor. The detention time needed to convert dissolved iron and manganese into filterable particles depends on the forms and concentrations of iron and manganese present, the type and concentration of oxidant employed, pH, temperature, and other water quality parameters, including the type and concentration of natural organic matter. Coagulants may need to be added to effectively remove colloidal iron and manganese.

The required reaction time for a particular system shall be determined, in consultation with KDHE, based on kinetic data and appropriate operating parameters. A minimum reaction time of at least 30 minutes shall be provided if oxidation is accomplished through aeration, unless a pilot study demonstrates that a shorter detention time will suffice. The detention basin should be designed with baffling to prevent short circuiting. Solids collection

is not required unless the detention basin is used as a sedimentation basin; but, provisions must be included in the design to flush solids from the detention basin when it is taken out of service for cleaning.

Oxidation of Fe^{+2} and Mn^{+2} with permanganate is quite rapid at pH 5.5 or higher. Oxidation of Fe^{+2} using free chlorine is quite rapid at pH 7 or higher, but oxidation of Mn^{+2} using free chlorine can be relatively slow. When using free chlorine to oxidize iron and manganese, residual Mn^{+2} can be removed using a stronger supplemental oxidant, e.g., permanganate, or by adsorption on manganese coated media (Subsection 2, below). Ozone and chlorine dioxide react rapidly with Fe^{+2} and Mn^{+2} , but can form small particles that can be difficult to filter. Iron complexed with natural organic matter reacts very slowly with oxygen, chlorine, and permanganate, and its removal may require additional treatment, e.g., coagulation or application of a stronger oxidant. Ozone can also oxidize manganese to permanganate, which can pass through a filter in dissolved form.

When oxygen is used as the oxidant, the reaction rate is very strongly dependent on pH, with oxidation of iron being very rapid above a pH of 7.5 and oxidation of manganese tending to be relatively slow below a pH of 9.5. Aeration alone may raise the pH to a high enough level (by removing CO_2); if not, a base (typically lime or sodium hydroxide) can be added to increase the reaction rate. Base addition may also be needed if there is not enough alkalinity present to counteract the acidity produced by the oxidation reactions. Since manganese oxidation is catalyzed by its own end product, manganese dioxide (a phenomenon referred to as autocatalysis), and since manganese is adsorbed by both iron hydroxide and manganese dioxide, a high pH is not necessarily needed for manganese removal, depending on the type of system employed and the concentrations of iron and manganese present. Residual manganese can also be removed by adsorption on manganese coated media, as described in Subsection 2, below.

- c. **DOSAGE CONSIDERATIONS** – The chemical feed system should be designed to provide at least the stoichiometric oxidant dosage for iron and manganese removal, assuming the highest anticipated influent concentrations and application of an appropriate safety factor that takes into consideration other possible sources of oxidant demand, e.g., sulfide, ammonia, and natural organic matter. However, the actual amount of oxidant required may be less than stoichiometric because ferric hydroxide and manganese dioxide can adsorb limited amounts of Fe^{+2} and Mn^{+2} .
- d. **SEDIMENTATION BASINS** – Sedimentation basins should be provided when treating water high in iron and/or manganese or where chemical coagulation is used to reduce the load on the filters. Provisions for solids removal must be made.

- e. FILTRATION – Filters shall be provided and shall conform to the requirements given in Section J on Filtration.

2. REMOVAL BY MANGANESE COATED MEDIA FILTRATION – In this process potassium permanganate or chlorine is fed, continuously or batchwise, to the influent of a manganese coated filter able to adsorb dissolved iron and manganese and to filter out particulate iron and manganese. This process is typically used primarily for manganese removal, since iron can be readily and less expensively removed by oxidizing it prior to filtration using oxygen or chlorine, as described in Subsection 1, above. Manganese is oxidized much more slowly by oxygen and chlorine, especially at the pH values typically employed, but residual manganese (and iron, if present) can be adsorbed on manganese coated media, provided that the coating is maintained in an oxidized state. This is accomplished by feeding permanganate or chlorine ahead of the media, usually continuously but also batchwise if necessary, e.g., during start-up or if desirable to extend the service cycle when regeneration is only intermittently required. The process must be carefully monitored to avoid underfeeding of permanganate or chlorine, which will impair process performance, or overfeeding of permanganate, which will impart a pink color to the finished water and cause black or brown manganese dioxide particles to form in the distribution system. The process is generally more efficient at pH values above 7.5 and is not practical for removal of iron complexed with natural organic matter (MWH, 2005). Neutral or slightly acidic pH values promote adsorption and subsequent oxidation of manganese, whereas alkaline pH values promote formation of manganese particles that must be removed using a filtration mechanism (Hargette & Knocke, 2001).

- a. Provisions should be made to feed the primary oxidant, typically oxygen, chlorine, or permanganate, to the raw water as far ahead of the filter as possible, and to feed permanganate or chlorine at a point immediately before the filter. The stoichiometric dosages for permanganate are 0.94 mg/L per mg/L of Fe^{+2} and 1.92 mg/L per mg/L of Mn^{+2} . When designing the feed system for permanganate addition (or any other oxidant) it is important to size the feeding capability to account for stoichiometric demand as well as demand exerted by other constituents in the water.
- b. Use of oxygen or free chlorine, in place of permanganate, to meet part of the oxidant demand is generally recommended as a cost-saving measure. If chlorine is used prior to filtration, a minimum free chlorine residual should pass through the filter in order to drive the reactions to completion. Post-chlorination may be necessary so that the required residual can be maintained in the distribution system. Oxidants that rapidly oxidize iron and manganese, e.g., ozone, chlorine dioxide, and permanganate, will convert them into particles that can be removed by filtration (Subsection 1 above) rather than by adsorption (Knocke *et al.*, 1988); but such particles may be more difficult to filter than those produced using oxygen or chlorine, especially if they are formed immediately prior to filtration.

- c. Sufficient capacity for the feeding of each oxidant being employed shall be provided.
 - d. The media may be natural greensand, anthracite, or silica sand having an effective size of 0.4 to 0.5 mm and a uniformity coefficient of 1.3 to 1.7. Other media types may be approved if their ability to develop and maintain a manganese oxide coating is demonstrated. A 6 inch (15.2 cm) cap of anthracite having an effective size of 0.8 mm and a uniformity coefficient no greater than 1.85 is recommended. The total filter media depth should not be less than 27 inches (70 cm). If an anthracite cap is used, the media depth should be 30 inches (76 cm), including the cap.
 - e. The filtration rate should not exceed 4.0 gpm/ft² (163 L/min-m²) and a design rate of 3.0 gpm/ft² (122 L/min-m²) is recommended. KDHE will on a case-by-case basis consider granting requests to operate at higher individual filter loading rates if the results of on-site pilot testing adequately support such requests.
 - f. The gravel support media must be of sufficient depth and size to uniformly distribute the backwash water. The backwash rate should be within the range of 15 to 18 gpm/ft² (611 to 733 L/min-m²). A means for maintaining proper backwash rates shall be provided. A backwash pump is recommended, in which case selection of the proper pump capacity and head is necessary. Where distribution system pressure and flow are used, a reliable flow indicator shall be provided. When using only water for backwashing, the backwash rate should be sufficient to fully fluidize the media when the water temperature is at its maximum value, typically about 15 to 18 gpm/ft² (611 to 733 L/min-m²) for conventional sand and greensand filters meeting the specifications stated in Subsection d above. However, it may be appropriate to specify lower backwash rates when employing air/water backwash systems, and such systems are now recommended to effectively clean the media. The designer must adequately justify the proposed air and water backwash rates. A means for maintaining proper backwash rates shall be provided. See Section J on Filtration for other pertinent design requirements for filters.
 - g. Sampling taps should be provided prior to application of the permanganate or chlorine, immediately ahead of filtration, and immediately following filtration. Also, sampling taps should be provided between the anthracite cap and the manganese coated media and halfway down the media.
 - h. Process wastes must be handled and disposed of as required by KDHE.
3. STABILIZATION BY SEQUESTRATION – Sequestration is a chemical treatment process used to keep iron and manganese in solution or suspension, thereby

eliminating or minimizing some of their adverse aesthetic effects. Sequestration is generally suitable only for concentrations of iron, manganese, or a combination of the two up to 1.0 mg/L for polyphosphate sequestration and up to 2.0 mg/L for sodium silicate sequestration. Sequestration may be less effective for manganese than for iron.

- a. POLYPHOSPHATES – Polyphosphates should be applied before chlorine is added for disinfection and after any other treatment for iron and manganese removal. Mixing in the water line should be thorough and complete before chlorination; and satisfactory chlorine residuals shall be maintained in the distribution system. Polyphosphate shall not be applied directly into the well for groundwater supplies, nor should water treated with polyphosphates be allowed to backsiphon into a well. Possible adverse impacts of polyphosphates on corrosion (and especially on lead levels at the tap) must be addressed when sequestration is proposed. Since polyphosphate may exert a dispersing action on accumulated deposits, frequent flushing of the system is recommended when polyphosphate treatment commences. The effectiveness of polyphosphate treatment may be adversely affected by calcium hardness (Klueh and Robinson, 1988).
 - 1) The phosphate chemicals employed must be appropriate for use in the production of drinking water (Subsection A.4.a.(1) of Chapter IX) and total phosphate applied shall not exceed 10 mg/L as PO_4 .
 - 2) Stock phosphate solution should be kept covered and disinfected by maintaining a free chlorine residual of about 10 mg/L. Phosphate solutions having a pH of 2.0 or less may be exempted from this requirement by KDHE.
 - 3) Polyphosphates shall not be applied ahead of iron and manganese removal treatment. The point of application shall be prior to any aeration, oxidation, or disinfection if no iron and manganese removal treatment is provided.
- b. SODIUM SILICATES – On-site pilot-plant tests are required to determine the suitability of sodium silicate sequestration, and the dosage needed, for the particular water being treated. This process is appropriate only for groundwater supplies prior to their contact with air (Recommended Standards, 2003). Rapid oxidation of the iron and manganese, e.g., using chlorine or chlorine dioxide, must accompany or closely precede sodium silicate addition. Injection of sodium silicate more than 15 seconds after oxidation may cause detectable loss of chemical efficiency. Dilution of feed solutions below 5 percent silica as SiO_2 should also be avoided for the same reason.

- 1) Sodium silicate shall not be applied ahead of iron and manganese removal treatment.
 - 2) The amount of silicate added shall be limited to 20 mg/L as SiO₂, and the amount of added and naturally occurring silicate shall not exceed 60 mg/L as SiO₂.
 - 3) The liquid sodium silicate employed must be appropriate for use in the production of drinking water (Subsection A.4.a.(1) of Chapter IX).
4. REMOVAL BY ION EXCHANGE – Ion exchange softeners should not be used for iron and manganese removal for water containing more than 0.3 mg/L of iron, manganese, or a combination of the two. Ion exchange is not acceptable for iron and manganese removal where the raw water, regenerant, or rinse water contains dissolved oxygen.
 5. REMOVAL BY LIME-SODA ASH SOFTENING – Iron and manganese are readily removed by lime softening because they are simultaneously precipitated (as carbonates and hydroxides) and rapidly oxidized (if oxygen is present) due to the high pH values associated with lime softening (Section K).
 6. SAMPLING TAPS AND TESTING EQUIPMENT – Smooth-nosed sampling taps shall be provided, for control purposes, for each raw water source, each treatment unit influent, and each treatment unit effluent. Testing equipment shall be provided for all plants. The equipment should have the capacity to accurately measure iron and manganese concentrations in low concentration samples that do not require dilution or in higher concentration samples by means of sample dilution. The method detection limit should be less than or equal to 0.10 and 0.05 mg/L for iron and manganese, respectively and preferably less than 0.01 mg/L for manganese. Where polyphosphate or sodium silicate sequestration is practiced, appropriate testing equipment should be provided.

P. AERATION AND AIR STRIPPING

Aeration is the addition of air to water for the purpose of adding oxygen to the water, e.g., for oxidation and removal of iron and manganese (Section O). Air stripping is the use of air to strip volatile constituents, such as dissolved gases and VOCs, from the water. Groundwaters and hypolimnetic surface waters are more susceptible to these contaminants than are streams and epilimnetic surface waters.

Dissolved gases include carbon dioxide, which is corrosive and increases the lime dosage required for softening (Section K); hydrogen sulfide, which is highly corrosive and can cause taste and odor problems (Section N); methane, which is explosive in high concentrations and can serve as a food source for microbial growth; chlorine dioxide, used as an oxidant and

disinfectant; radon, a naturally occurring radioactive gas; and excessive amounts of oxygen and nitrogen, which are typically responsible for gas supersaturation problems. Most VOCs, like many taste and odor substances, can also be effectively removed by adsorption on GAC (Section Q), so both air stripping and adsorption are typically evaluated for treatment of VOC-contaminated water supplies; however, few taste and odor producing substances can be effectively removed by aeration.

Air strippers used to remove carbon dioxide and hydrogen sulfide also serve to aerate the water, thereby facilitating removal of iron and manganese. Carbon dioxide levels greater than 10 mg/L may be more economically removed by air stripping than by lime addition. Air stripping is commonly employed for hydrogen sulfide removal when the concentration is 0.6 mg/L or greater. Concurrent removal of carbon dioxide and hydrogen sulfide may not be practical because the loss of carbon dioxide, which is more volatile than hydrogen sulfide, may raise the pH sufficiently to convert a significant fraction of the hydrogen sulfide to the bisulfide ion, which is not strippable. (Approximately 50% of the sulfide will present as bisulfide, rather than hydrogen sulfide, at pH 7.) When aeration is used to remove hydrogen sulfide, it should be done prior to coagulation or softening.

1. METHODS – Natural draft aeration, forced or induced draft aeration, packed tower aeration, air stripping, and pressure aeration are approved methods. Spray aeration is not recommended by KDHE. Other methods may be used if applicable to the treatment needs. Such methods include but are not restricted to fine- and coarse-bubble diffusion, cascade aeration and air stripping, mechanical aeration, and membrane permeation. The method employed must be suitable to meet the particular needs of the water to be treated and is subject to approval by KDHE.
2. PROTECTION – All aerators and air strippers except those discharging to a lime softening or coagulation process followed by filtration shall be protected from contamination by birds, insects, wind-borne debris, rainfall, and water draining off the exterior of the aerator or air stripper.
3. DISINFECTION – Aerators and air strippers shall be disinfected according to AWWA Standard C653 before being placed into service.
4. STABILIZATION – The stability of the finished water following aeration should be determined and, if necessary, adjusted by additional treatment (Section L).
5. DESIGN CRITERIA
 - a. NATURAL DRAFT AND FORCED OR INDUCED DRAFT MULTI-TRAY AERATION SYSTEMS – Forced or induced draft systems are preferred over natural draft systems. Natural draft systems are typically used for aeration (especially for iron and manganese removal) and for stripping out carbon dioxide and methane. Forced draft systems are commonly employed for aeration and/or to remove dissolved gases, and may in some cases be

effective for VOC removal (e.g., for a highly volatile compound present at a relatively low concentration). Designs for these types of systems should provide:

- 1) Uniform distribution of water over the top tray.
- 2) Perforations in the distribution pan 0.2 to 0.5 inches (0.5 to 1.3 cm) in diameter, spaced 1 to 3 inches (2.5 to 7.6 cm) on centers to maintain a 6 inches (15.2 cm) water depth.
- 3) Discharge of the water through a series of trays. Natural draft systems should have three or more trays separated by not less than 12 inches (30.5 cm) between trays. Induced draft systems should have five or more trays separated by not less than 6 inches (15.2 cm) between trays.
- 4) Inert media, such as coke, ceramic balls, limestone, or (preferably) synthetic packing that will not disintegrate due to freezing cycles. Typical media depths range from 8 to 12 inches (20.3 to 30.5 cm); but trays without media can also be used. A slat-type design may be more appropriate than a design employing media or trays where there is significant potential for clogging and deposition.
- 5) Justification of the design loading rates.
- 6) Trays with slotted, heavy wire mesh (0.5 inch or 1.3 cm openings), or perforated bottoms.
- 7) Construction using durable materials and components acceptable for use in contact with potable water and resistant to the aggressiveness of water, dissolved gases, and potable-water-compatible cleaning materials.
- 8) Prevention of water loss from either type of system by wind carriage by enclosure with louvers sloped to the inside at an angle of approximately 45°.
- 9) Insect control using non-corrodible 24-mesh screen.

In addition, forced or induced draft systems shall be designed to:

- 1) Ensure that the water outlet is adequately sealed to prevent unwarranted loss of air.

- 2) Include a blower that is both adequately protected from the elements and properly screened. In some systems, electrical interconnection of the blower, disinfectant feeder, and well pump may be appropriate. A backup motor for the air blower must be readily available, particularly when necessary to maintain compliance with an MCL.
 - 3) Ensure adequate flow of air through the aerator or air stripper.
 - 4) Include a down-turned and screened (24-mesh) air inlet and a screened (4-mesh) outlet. The screens shall be composed of non-corrodible material.
 - 5) Ensure that the air introduced into the column is as free as possible from contamination such as fumes, dust, dirt and oil.
 - 6) Provide easy access to internal surfaces, components, and media for inspection, cleaning, maintenance, repair, and replacement. If removal of trays or other heavy parts will be necessary for maintenance, consideration should be given to installing a crane.
 - 7) Address potential plugging or fouling problems (e.g., those associated with precipitation of calcium carbonate, deposition of iron and manganese compounds, or biological growths, which may decrease air flow and adversely affect contaminant removal) by providing access (Subsection 6, above), suitable means for cleaning and/or replacing media, and appropriate pre- and post- treatment. Post-filtration for removal of precipitated solids or bacterial slimes may be necessary for installations treating groundwater, and disinfectant application points may be needed both before and after units in which biological growths may occur.
 - 8) Discharge the exhaust air directly to the outside atmosphere or, where applicable, into a treatment unit designed to remove contaminants from the air stream prior to discharge to the outside atmosphere. The applicant should contact KDHE prior to submission of a permit application to determine if a permit will be required under the Clean Air Act.
 - 9) Provide noise control, as needed, especially when located near residential areas.
- b. **PRESSURE AERATION** — Pressure aeration is aeration of water using compressed air and diffusers to release bubbles into the water. It may be used for oxidation purposes only if a pilot-plant study indicates the method is applicable. It is not acceptable for removal of dissolved gases. Filters

following pressure aeration must have adequate exhaust devices for release of air. Pressure aeration devices shall provide:

- 1) Thorough mixing of compressed air with the water being treated.
 - 2) Screened and filtered air, free of fumes, dust, dirt, and other contaminants, supplied by an oil-less type compressor.
- c. **AIR STRIPPING** – Forced draft systems (Subsection 5.a) may be effective for air stripping of some constituents; but packed towers are generally used to remove less volatile constituents, including most VOCs, especially when a high degree of removal is required. In a packed tower, contaminated water is pumped to the top of the tower and distributed over the cross-sectional area of the tower, which is filled with a highly porous packing material. Typically, air is introduced at the bottom of the tower and flows upward, counter to the downward water flow; but cross-flow systems may be advantageous in some applications. The packing material serves to maximize the water surface area in the tower, since transfer of volatile contaminants from the water to the air occurs at the air/water interface.

Generally, packed towers are feasible for removing compounds with a Henry's constant greater than 100 atm-mol/mol. For compounds having a Henry's constant between 10 atm-mol/mol and 100 atm-mol/mol, packed tower air stripping may be feasible, but should be carefully evaluated using pilot studies. A two-stage packed tower system instead of a single-stage packed tower system may be required to obtain the necessary removals for compounds having Henry's constants in this range.

An air stripper should be designed to remove the target contaminants from the water to concentrations significantly below their respective MCLs and, preferably, to the lowest levels that are practical. The effect of temperature must be considered, since a drop in water temperature can result in a significant drop in removal of the contaminants(s) of interest. Unless an alternate source of supply is available, redundant capacity may be necessary to ensure compliance with applicable MCLs when the largest air stripper is down for cleaning, maintenance, or repair.

The mass transfer approach to packed tower design is well developed and computer models are widely available to facilitate preliminary design; but traditional forced draft systems and various other stripping systems have not been as extensively modeled in the literature as the packed tower, especially for VOC removal. For these systems, the initial design should be based on manufacturers' recommendations and confirmed through actual performance data from similar installations or through pilot studies.

KDHE recommends that small-scale pilot studies be conducted using the actual water to be treated to confirm both the effectiveness of the proposed air stripper design and the accuracy of the mass transfer coefficients used to estimate contaminant removal, preferably at the peak contaminant concentration(s) anticipated. Pilot studies could also evaluate various areal loading rates and air-to-water ratios so that the design can be optimized with respect to cost and performance. The ratio of the column diameter to the packing diameter should be at least 7:1 for the pilot unit, and the type and size of packing used in the full-scale unit should be the same as that used in the pilot study.

In cases where considerable performance data are available on the contaminants to be removed, at concentrations similar to those in the water to be treated, KDHE may approve the process design based on appropriate calculations and supporting data, without pilot testing. Proposals of this type should be discussed with KDHE prior to submission of a permit application.

Packed-tower air strippers shall be designed in accordance with the applicable guidelines provided in Subsection 5.a, above, for forced draft systems. Additional design requirements and considerations for packed-tower air strippers are as follows:

- 1) The applicant shall specify the flow pattern (countercurrent or crosscurrent) and provide justification for the design parameters selected, including tower height and diameter, air and water areal loading rates, Henry's constant(s), mass transfer coefficient(s), air pressure drop, and packing depth. The ratio of the column diameter to packing diameter shall be at least 10:1.
- 2) The minimum volumetric air-to-water ratio at peak water flow should be at least 25:1. The maximum gas and liquid loading rates must be selected such that "flooding" of the tower will be avoided by a reasonable margin of safety. A packed tower is said to be "flooded" when the gas and water loading rates are so high that an excessive gas pressure drop occurs and the passage of the water through the tower is impeded. This results in unstable operation, excessive energy use, impaired performance, and the possibility that water will be discharged out the top of the column (i.e., flooding in the common sense of the word).
- 3) The tower can be constructed of stainless steel, concrete, aluminum, fiberglass, or plastic. Uncoated carbon steel is not recommended because of corrosion. Towers constructed of light-weight materials shall be provided with adequate support to prevent wind damage.

- 4) Water should be distributed uniformly over the media at the top of the tower using spray nozzles or orifice-type distributor trays that prevent short circuiting. For multi-point injection, one injection point for every 30 square inches (194 cm²) of tower cross-sectional area is recommended.
- 5) A mist eliminator shall be provided above the water distributor system.
- 6) A redistribution ring shall be provided at least every 10 ft. (3 m) to prevent water channeling along the tower wall and short circuiting.
- 7) The effluent sump, if provided, shall have easy access for cleaning and be equipped with a drain valve. The drain shall not be physically connected directly to any storm or sanitary sewer. At a minimum an air-gap separation shall exist between the drain line and any sewer or receiving structure connected to a sewer.
- 8) A blow-off line should be provided in the effluent piping to allow for the discharge of water/chemicals used to clean the tower.
- 9) The design shall prevent freezing of the influent riser and effluent piping when the unit is not operating. Arranging the influent riser and effluent pipes so that they self-drain when the unit is not operating should be considered. If piping is buried, it shall be maintained under positive pressure.
- 10) The water flow to each tower shall be metered.
- 11) An overflow line shall be provided that discharges 12 to 14 inches (30.5 cm to 35.6 cm) above a splash pad or drainage inlet. Proper drainage shall be provided to prevent flooding of the area.
- 12) A suitable flow control valve should be used to control flow in the water effluent line and to minimize air entrainment.
- 13) Means shall be provided to prevent flooding of the air blower.
- 14) The water influent pipe should be supported separately from the tower's main structural support.
- 15) The air inlet shall be in a protected location.
- 16) An air flow meter shall be provided on the influent air line or an alternative method to determine the air flow shall be provided.

- 17) A positive air flow sensing device and a pressure gauge must be installed on the air influent line. The positive air flow sensing device must be a part of an automatic control system which will turn off the influent water if positive air flow is not detected. The pressure gauge will serve as an indicator of fouling or flooding.
 - 18) Tower effluent collection and pumping wells shall be constructed to clearwell standards.
 - 19) Provisions should be made for extending the tower height without major reconstruction.
 - 20) The packing support shall be adequate to prevent deformation of the media or column with deep packing heights while allowing the free flow of water.
 - 21) The foundation shall be designed to adequately support the tower and provide enough lateral support to prevent overturning due to wind loading. The design of the foundation as well as that of the tower shall take into account the possibility of the tower being liquid full, e.g., due to inadvertent flooding or to submergence of the media during cleaning.
 - 22) An access ladder with safety cage shall be provided to permit inspection of the tower including the exhaust port and mist eliminator.
 - 23) Monitoring devices (with alarms and, if needed, telemetry) should be provided to detect excessive fouling, flooding, overflow, significant pressure fluctuations, lack of positive air flow, and other operating conditions that could adversely impact contaminant removal.
 - 24) Air blowers should be housed to protect the equipment and related appurtenances and to help control noise. A standby blower will be required if necessary to ensure the availability of an adequate supply of potable water. Air blowers shall be of the oil-free type.
- d. BYPASS – A bypass should be provided for all aeration units except those installed to comply with MCLs, in which case no bypass shall be provided unless specifically approved by KDHE.
- e. SAMPLING TAPS, TESTING EQUIPMENT, AND MONITORING – Provide appropriate influent and effluent sampling taps and equipment to test for dissolved oxygen, pH, temperature, carbon dioxide, sulfide, and VOCs, as applicable. Sampling lines from the sampling taps located along the height of

the stripper shall be valved at an elevation that permits safe access and facilitates maintenance and drainage. Sampling lines shall be protected from freezing. After the air stripper is in service, regular monitoring for the target contaminant(s) in the influent and effluent of the stripper will be required.

Q. ADSORPTION WITH GAC

Activated carbon is available in powdered and granular forms (PAC and GAC). PAC usage is generally limited to taste and odor control or seasonal control of pesticides, and design of PAC systems is addressed in Subsection N.4. GAC is commonly used in filter-adsorbers (Subsection J.5.4), primarily for taste and odor control, but may also be used in adsorbers, following filtration, typically for the removal of trace organics, including taste and odor causing compounds and disinfection byproduct precursors. GAC can be also used to remove chlorine and certain inorganics such as radon and mercury, but these applications are limited.

Adsorption on GAC is also a BAT process for compliance with the MCLs for TTHMs and HAA5 (KAR 28-15a-64). Two alternatives are provided: GAC10, involving an empty bed contact time of 10 minutes and a carbon reactivation frequency of 120 days for Subpart V (locational running annual average) compliance and 180 days for Subpart L (running annual average) compliance; and GAC20, involving an empty bed contact time of 20 minutes and a carbon reactivation frequency of 240 days.

1. DESIGN BASIS – Predictive tools such as diffusion or mass transfer models, laboratory-scale column tests, and isotherm measurements can provide a basis for the preliminary design. Isotherm constants for numerous contaminants (organic and inorganic, toxic and potentially toxic) have been published, but care must be exercised in their interpretation and use (Randtke and Snoeyink, 1983). Depending on the complexity of a proposed installation, laboratory or pilot-plant column studies using the actual water to be treated may be required. Pilot studies, employing contactor conditions based on isotherm data or laboratory columns, can provide a valuable indication of performance at full scale. Also, pilot studies provide data that can be used to calibrate various widely used adsorption models. The design engineer should submit to KDHE a detailed proposal for a laboratory, modeling, and/or pilot-plant study appropriate for a particular project and seek KDHE approval prior to conducting the tests. The proposal should also identify the source(s) of the contaminants, their frequency of occurrence, and abatement schedules.

Major process design considerations for a GAC adsorber include the following:

- a. Design flow rate;
- b. Nature and concentration of the contaminants to be removed;
- c. MCLs or other regulatory limits pertaining to the contaminants of concern;

- d. Type, size, and adsorptive characteristics of the GAC to be utilized in the adsorber;
- e. Adsorber type (e.g., steel or concrete, upflow or downflow, gravity or pressure, etc.), dimensions, number, and arrangement (series or parallel);
- f. Location of the adsorber(s) in the water treatment process;
- g. Superficial (approach) velocity (or areal loading rate);
- h. Minimum empty bed contact time required for removal of the contaminants to concentrations significantly below their respective MCLs and, preferably to the lowest levels that are practical.
- i. Bed depth of GAC in the adsorber(s);
- j. Expected service time (bed life) of the adsorber(s); and
- k. Identification of the parameters that will be monitored to evaluate process performance, and development of a corresponding process monitoring and control program.

2. CONTACTOR TYPE AND NUMBER – GAC adsorbers may be upflow or downflow, and can operate under pressure or by gravity. Upflow units can operate with packed or expanded beds. Downflow, gravity contactors are recommended for water treatment applications. Multiple adsorbers can be operated in series or in parallel. Adsorbers used for water treatment are typically operated in parallel; but operation in series may be justified if a high degree of removal is required, if adsorption is rapid (i.e., the mass transfer zone is small relative to the bed depth), and if adsorption is favorable (i.e., the adsorption front is non-spreading). Where only two units are provided, each unit shall be capable of meeting the maximum daily demand. Where more than two units are provided, the contactors shall be capable of meeting the maximum daily demand with one or more units removed from service, as determined in consultation with KDHE.

3. MEDIA REQUIREMENTS

- a. The GAC shall conform with AWWA Standard B604. Only Virgin GAC or GAC regenerated from this application is acceptable because of possible contamination of carbon from other sources.
- b. GAC selection is based on head loss, backwash characteristics, hardness, rate and capacity for adsorption, and overall process cost. Both 8 x 30 and 8 x 20 mesh GAC are commonly used for filter adsorbers and 12 x 40 mesh GAC is commonly used for post-filter adsorbers. The head loss is less in the larger 8

x 30 mesh carbon but the rate of adsorption is slower as compared to the smaller 12 x 40 mesh carbon.

4. MATERIALS OF CONSTRUCTION – Since GAC is corrosive when wet, special attention must be given to the adsorber's construction. The columns should be constructed of non-corrosive material such as fiber glass or lined mild steel. The lining materials must be approved for use in potable water applications and be resistant to abrasion by GAC particles.
5. COMPETITIVE ADSORPTION – Analysis of the water should extend beyond the regulated compounds since other compounds, especially naturally occurring organic matter (typically measured as total organic carbon), may have a very significant impact on the design, operation, and performance of the adsorber. Competitive adsorption by natural organic matter may greatly decrease both the rate and extent of adsorption of regulated compounds, necessitating greater contact times and/or more frequent replacement of the GAC to comply with the applicable MCLs.
6. WATER STABILITY – The stability of both the treated and untreated water must be ascertained and adjusted if necessary (Section L). A depositing water may rapidly clog the pores of the GAC while an aggressive water could corrode valves, piping, and media supporting materials.
7. DISINFECTION AND BIOLOGICAL ACTIVITY – Disinfectants do not prevent biological growth from occurring on GAC because they react with GAC. Further, since GAC has the capacity to de-chlorinate water, disinfection should follow the GAC adsorbers. Disinfection requirements for start-up of filters (Section J and AWWA Standard C653) also apply to adsorbers and filter-adsorber vessels; however, the disinfection of the adsorber vessels must be completed prior to loading the vessels with GAC as residual chlorine reacts with GAC. AWWA Standard B604 recommends microbial testing of a GAC filter before it is placed in service. Biologically active GAC may improve removal of trace organics; but such activity must be controlled to avoid undesirable effects.
8. BACKWASHING – Provisions for backwashing must be made to remove carbon fines and particulate matter that may accumulate in the GAC bed and to restratify the media. Backwash water should not be chlorinated, or should be de-chlorinated to prevent loss of adsorptive capacity due to chlorine contact with the carbon surface. If the source of water for backwashing the adsorber is the public water supply, proper cross-connection protection must be provided. The backwash water drain line shall not be physically connected to any storm or sanitary sewer; at a minimum, an air-gap separation shall exist between the drain line and any sewer or receiving structure connected to a sewer.

The backwash system should be designed to accomplish the following:

- a. Expand the carbon bed for cleaning while avoiding excessive carbon loss or structural damage to the interior of the vessel.
- b. Settle the carbon bed in a stratified state so that the adsorptive wave front will be at least partially maintained, thereby reducing carbon usage.

Disposal of backwash water and spent GAC must be in a manner approved by KDHE.

- 9. REGENERATION OF SPENT GAC – On-site thermal regeneration is usually limited to larger PWSSs. Large and intermediate-sized plants may use off-site regeneration facilities but these plants and their transportation units must not use carbon that has been put to any other use. Small plants normally replace their spent GAC with virgin GAC.
- 10. RADON – When GAC adsorbers are used to remove radon, adequate shielding and other safeguards must be provided for both operators and visitors. The spent GAC may require disposal as radioactive waste in accord with Nuclear Regulatory Commission regulations and must be disposed of in a manner approved by KDHE.
- 11. SAFETY – GAC adsorbs oxygen from the air. Therefore, enclosed spaces where GAC is stored must be adequately ventilated and equipped with oxygen monitors, alarms, and other appropriate safety features. See Chapter IX for additional information regarding PAC storage and handling that may pertain to GAC storage and handling.

R. REMOVAL OF TRACE INORGANIC CONTAMINANTS AND RADIONUCLIDES

General regulatory and design requirements for inorganic contaminants (IOCs) and radionuclides are described in Sections B.6 and B.7 of this chapter, respectively. For inorganic contaminants and radionuclides not adequately removed by existing or proposed treatment processes, additional treatment(s) sufficient to meet the applicable MCLs is required. Depending on the particular contaminant(s) involved, it may be possible to accomplish this using a process described in another section of this chapter. This section presents general requirements for processes not described in other sections of this chapter, specific requirements for selected processes, and information regarding selected contaminants.

1. GENERAL REQUIREMENTS

- a. A process not described in detail elsewhere in Chapter V will in most cases be considered by KDHE to be a new process. See Chapter III, Subsection A.5 for general requirements for new processes.

- b. Data from laboratory studies, pilot-plant tests, or full-scale demonstrations may be required to justify the basis of design. The design engineer should consult with KDHE prior to conducting such tests or submitting a permit application.
- c. IOCs and radionuclides can accumulate in waste streams, rendering them hazardous and/or precluding the use of disposal methods that might otherwise be suitable for such wastes. Waste streams containing IOCs or radionuclides must, like wastes from any other process, be disposed of in a manner approved by KDHE; but special requirements may apply due to the nature of the contaminants being removed.
- d. Removal of trace contaminants can depend heavily on their physical state (e.g., dissolved or particulate), their oxidation state, and whether they are complexed with other constituents. For example, barium, radium, and arsenic can be present in a water supply in both dissolved and particulate forms; and the dissolved forms can typically be removed by ion exchange but not by filtration, whereas the opposite is true of the particulate forms. As(III) may need to be oxidized to As(V) before it can be adequately removed by some of the treatment processes listed in 40 CFR 141.62. A process suitable for removing Hg(II) may not work well for methylmercury or for mercury complexed with chloride ions or natural organic matter. In such cases, the nature of the contaminant must be adequately considered when selecting and designing a treatment process to remove it.
- e. Changes in pH can significantly influence both the nature of a contaminant (e.g., its physical state or the valence of its dissolved form) and the performance of a treatment process designed to remove it. Depending on the circumstances, the design engineer may be required to submit supporting data to show that process performance has been optimized with respect to pH or that the process performs well over the range of pH values that will be encountered. The effects of pH changes made to improve process performance and other impacts of the process on water quality (e.g., changes in hardness or TDS) must be adequately accounted for when assessing the stability of the finished water (Section L).

2. ION EXCHANGE, ADSORPTION ON ACTIVATED ALUMINA, AND OTHER ADSORPTIVE PROCESSES

- a. Ion-exchange softening (Section K) can effectively remove certain cationic IOCs such as Ba^{+2} and Ra^{+2} . Anion exchange resins can be used to remove anionic IOCs such as arsenic, chromium, and nitrate, as well as perchlorate, which may be regulated in the future. In some cases it may be advantageous to use an ion exchange resin tailored by the manufacturer to selectively adsorb a specific contaminant.

Activated alumina and other adsorbents (some of them proprietary in nature) can also be used to remove IOC's. In many cases the primary removal mechanism is ion exchange, but other mechanisms can be involved, e.g., oxidation or reduction, complexation, and precipitation. Activated alumina has been designated by the USEPA as a BAT for removal of arsenic, beryllium, and selenium, and it can also be used to reduce excessive levels of fluoride to achieve compliance with the SMCL for fluoride. A number of proprietary and non-proprietary adsorbents are available for arsenic removal. Radium can be removed using a radium selective adsorbent or manganese greensand filtration.

For additional information regarding ion exchange, adsorption on activated alumina, and removal of various IOC's by adsorptive processes, the reader is encouraged to consult Clifford (1999) and Gottlieb (2005).

- b. Important considerations in the design of these processes include:
- 1) The applicable provisions of Subsections 1 through 8 of Section Q (which specifically address adsorption on GAC but in many cases are broadly applicable to any adsorptive process);
 - 2) The capacity of the adsorbent for the contaminant(s) of interest (when used to treat the source water in question under conditions equivalent to those expected in the full-scale facility) and, for adsorbents that will be periodically regenerated, the capacity of the adsorbent after it has been repeatedly regenerated;
 - 3) The useful life of the adsorbent, recognizing that some adsorbents (e.g., anion exchange resins) tend to degrade over time while others may degrade physically (e.g., during backwashing) or chemically (e.g., during regeneration) or may become fouled by contaminants that are not completely removed during regeneration;
 - 4) The presence of other constituents in the water that may effectively compete for adsorption sites (reduce the capacity of the adsorbent for the contaminant of interest), especially those able to chromatographically displace ("dump") the contaminant(s) of interest (e.g., displacement of nitrate or arsenic from an ion exchange column by sulfate), and variations in the concentrations of such constituents;
 - 5) The presence of constituents in the water that may foul the adsorbent because they are not adequately removed during regeneration (as can happen when natural organic matter binds to anion exchange resins) and variations in the concentrations of such constituents;

- 6) The potential for the adsorbent to leach constituents into the water (e.g., the odorous degradation products that can leach from anion exchange resins and the potential for aluminum to be released from activated alumina) and measures to monitor and control such leaching;
 - 7) The potential for the adsorbent to react with chemical oxidants or disinfectants and to produce byproducts or necessitate boosting of the residual disinfectant concentration;
 - 8) The possible need for pH control, a suitable means of controlling pH when needed, and stabilization of the finished water (Section L).
 - 9) A means of backwashing the adsorbent to remove accumulated solids and a means of measuring the pressure drop through the adsorbent bed;
 - 10) The frequency of regeneration, the chemicals used for regeneration (which are subject to approval by KDHE), regenerant loading rates and volumes, regenerant storage and feeding facilities (Chapter IX), the pros and cons of cocurrent versus countercurrent regeneration, rinsing requirements, and disposal of spent regenerant, rinsing solutions, and adsorbents; and
 - 11) Operating procedures, including protocols for ensuring compliance with the applicable MCL(s) and for protecting the quality of the finished water, especially when blending is required, as is often the case when removing nitrate or fluoride.
- c. Barium and radium adsorb more strongly than calcium and magnesium to the resins used for ion-exchange softening; but they are typically not well removed during regeneration. Therefore, the apparent adsorptive capacity of the resin for barium and radium will decrease after a number of regeneration cycles. Furthermore, the calcium and magnesium (hardness) ions will gradually push the barium and radium ions toward the effluent end of the column, which can potentially lead to exceedance of the MCL for barium or radium. Possible preventive measures include initiating a regeneration cycle when hardness begins to break through, employing countercurrent regeneration, or using a calcium-form cation exchange resin.
- d. Although some adsorbents are able to effectively remove As(III), anion exchange resins, activated alumina, and other resins adsorb As(V) much more strongly than As(III). In such cases, a preoxidation step should be included to convert all of the arsenic to As(V). Additional information on arsenic

removal has been published by Clifford (1999), USEPA (2003a), and Gottlieb (2005).

- e. Uranium can be effectively removed by strongly basic anion exchange resins operating at pH values between 6.0 and 8.2, but a relatively strong regenerant is needed to remove uranyl carbonate ions from the resin (Gottlieb, 2005).

3. ELECTRODIALYSIS (ED) AND ELECTRODIALYSIS REVERSAL (EDR)

ED and EDR are electrically driven membrane processes. The flow passes through a series of parallel channels separated by alternating anion and cation exchange membranes; and an electrical charge causes the ionic species present in the water to migrate through the membranes, leaving deionized water in one set of alternating channels and a more saline concentrate in the other channels. Each set of channels is manifolded together to produce a stream of deionized water and a stream of concentrate. EDR differs from ED in that the charge is periodically reversed. Reversing the charge reverses the deionized and concentrate streams and can reduce membrane fouling and scaling problems. For additional information, the reader is encouraged to consult Taylor and Wiesner (1999) and Bergman (2005).

Since ED and EDR involve the use of membranes to produce a concentrate stream, they are typically classified as membrane processes and they are, in some ways, similar to the pressure-driven processes described in Section S. However, there are some very significant differences between these two types of processes. ED and EDR membranes are relatively porous membranes that are not effective in removing particulate contaminants and natural organic matter. Furthermore, the water being treated does not travel through the membranes; instead, only the small ionic contaminants being removed move through the membranes. Thus, contaminants are removed on the basis of charge and not size. Accordingly, ED and EDR do not meet the definition of a membrane filtration process under 40 CFR 141.2 and are therefore not eligible for credit for removal of *Cryptosporidium* oocysts.

Important considerations in the design of ED and EDR processes include:

- a. Pretreatment requirements;
- b. Power requirements, limiting current density, current leakage, and proper handling of the water from electrode compartments (Bergman, 2005);
- c. Membrane life and fouling potential;
- d. The potential for scale formation on surfaces in contact with the concentrate;
- e. Temperature effects on process performance;

- f. Post-treatment requirements (Section L); and
- g. Proper disposal of brine and cleaning solutions.

S. MEMBRANE PROCESSES

A membrane is a thin layer of material that allows some constituents to pass through while rejecting (removing) others. Depending on the type used, membranes can be used to remove contaminants ranging in size from small ions to macromolecules (e.g., humic substances) to relatively large particles. Thus, membranes have numerous potential drinking water treatment applications.

Membrane processes may be classified on the basis of the driving force employed and the type of membrane used. Most membrane processes used for drinking water treatment are pressure driven, including reverse osmosis (RO), nanofiltration (NF), ultrafiltration (UF), and microfiltration (MF). Electrically driven processes, such as electrodialysis (ED) and electrodialysis reversal (EDR), employ ion exchange membranes and are used primarily to demineralize water. They effectively remove certain IOC's (Section R); but they do not effectively remove unionized contaminants or particles. Temperature and concentration driven membrane process, e.g., thermoosmosis and dialysis, are used primarily for laboratory and industrial purposes.

RO can effectively remove salts (small ions) and larger constituents from water. To overcome the osmotic pressure of the feed water, and to achieve a reasonable water flux (water flow rate per unit of membrane area) through a relatively "tight" membrane, RO processes typically operate at moderate to high pressures, e.g., 90 to over 1,000 psi (620 to 6,900 kPa), depending on the concentration of total dissolved solids (TDS) in the feed water and the desired recovery (percentage of the feed water passing through the membrane). RO is listed as a BAT for eleven inorganic compounds regulated in 40 CFR 141.62(b) as well as four radionuclides regulated in 40 CFR 141.66(b) through (e), and it is capable of effectively removing numerous regulated synthetic organic chemicals (40 CFR 141.61(c)).

NF membranes achieve only partial removal of salts but are particularly effective for removing divalent cations and natural organic matter (DBP precursors). Because they can remove calcium and magnesium they are sometimes referred to as "softening membranes." Since they do not reject smaller ions, such as sodium and chloride, as well as RO membranes do, they are subject to much lower osmotic pressures and are typically operated at much lower pressures, e.g., 50 to 150 psi (345 to 1034 kPa). NF membranes are very effective for DBP precursor removal, and NF with a molecular weight cutoff of less than 1000 Daltons is a BAT process for compliance with the Subpart V (locational running annual average) MCLs for TTHMs and HAA5 (40 CFR 141.64).

UF membranes are used to remove molecules, especially organic molecules, larger than a specified size, usually expressed as an apparent molecular weight cutoff, which can vary from about 500 Daltons (atomic mass units) to greater than 150,000 Daltons. However, UF

membranes having molecular weight cutoffs in the 30,000 to 150,000 Daltons range typically exhibit little, if any, removal of dissolved organics that form disinfection byproducts. MF membranes remove particles, typically those larger than about 0.1 to 0.5 microns (micrometers); but they do not remove dissolved substances, including true color, unless the dissolved substances are first converted into particulate form (e.g., by precipitation or by adsorption on a solid adsorbent). MF membranes may be useful for removing protozoan cysts and other organisms when recovering filter backwash water.

Typical operating pressures are 5 to 40 psi (34.5 to 280 kPa) for UF and MF. UF and MF membranes may also be operated under vacuum or by gravity, since the required operating pressure for some applications may be significantly less than atmospheric pressure; and such membranes are commonly referred to as submerged (or immersed) membranes because they can be placed in an open basin rather than being confined in a pressure vessel.

Membranes may also be classified based on their composition and configuration. Membranes composed of cellulose acetate, cellulose acetate blends, cellulose triacetate, and polyamide have been available for many years; and membranes composed of many other materials, including polysulfone, polycarbonate, polyolefins, polyvinylidene fluoride, and ceramics, have more recently become commercially available. These materials exhibit a broad range of physical and chemical properties, which not only enable them to be tailored to individual applications but also give rise to differences in membrane life, fouling resistance, chemical and biological resistance, mechanical degradation, and pretreatment requirements. Manufacturers and suppliers should be contacted to identify all critical design issues applicable to the particular types of membranes being considered for a particular application (Bergman, 2005).

Virtually all membranes employed in drinking water treatment plants are either spiral wound or hollow fine-fiber. RO and NF membranes used for drinking water treatment are usually spiral wound, while hollow fine-fiber membranes are more commonly used for UF and MF applications and for applications involving membrane backflushing. Other configurations, including flat-sheet and tubular membranes, are used primarily for laboratory or industrial applications.

Individual membrane elements (or modules) are contained in housings (or vessels), with a typical RO or NF housing containing four to eight spiral-wound elements in series. Groups of housings are typically manifolded together in parallel, acting as a single unit (referred to as a bank or train), which simplifies process operation and maintenance. Redundancy can be achieved by placing an adequate number of banks in parallel, such that the desired flow can be achieved while one bank is out of service; and increased product water (permeate) recovery can be achieved by staging banks in series, e.g., by extracting additional product water from the concentrate leaving an earlier stage of a multistage (or multipass) system. It is also possible to deploy two different types of membranes in series (e.g., UF followed by RO, thereby reducing fouling of the RO membranes) or in parallel (e.g., UF and RO, thereby producing a water that is not completely demineralized).

RO, NF, UF, and MF membranes can effectively remove bacteria and protozoan cysts, and RO, NF, and UF membranes (but not MF membranes) can effectively remove viruses. However, membrane processes are not 100% effective in removing pathogens from drinking water due to membrane imperfections, leaking seals, bypass lines, and other factors. Therefore, safeguards must be in place to ensure that a treatment sequence which utilizes a membrane system consistently achieves the log removal/inactivation credits it has been recognized as being able to achieve; and careful consideration must be given to the disinfection requirements of the product water and to the residual disinfectant used to protect the quality of the water in the distribution system. KDHE will not grant 100% of the required log removal/inactivation credits for microbes to the membrane system alone. See Subsection 4.f, below.

Incorporation of a membrane treatment system into the treatment scheme will be approved by KDHE upon demonstration of feasibility by the design engineer and the submission of an acceptable plan for disposal of all wastes generated by the membrane process. Prior to initiating the design of a membrane treatment facility, KDHE should be contacted to determine if a pilot study will be required to demonstrate feasibility, i.e., to demonstrate such things as: membrane performance (water flux, product water recovery, and contaminant removal) for cold and warm water and after prolonged membrane use; the effectiveness of membrane cleaning procedures in preventing long-term fouling; and the adequacy of the proposed pre- and post- treatment processes. Since pilot plants are typically run only for a short period of time (e.g., several months) relative to the typical life of a membrane, and since raw water quality may vary during the expected life of the facility, appropriate safety factors must be applied to critical design parameters. At the conclusion of a pilot study, the membranes used in the pilot study should be subjected to non-destructive and destructive (autopsy) tests to characterize changes in performance and to better understand the reasons for any fouling that may have occurred.

Plans and specifications must address each of the items below, many of which will be included in the demonstration of feasibility. Additional information pertaining to the design and operation of membrane treatment systems can be found in USEPA's *Membrane Filtration Guidance Manual* (USEPA, 2005) and manuals of practice published by AWWA (AWWA, 1999c and 2005a).

1. RAW WATER QUALITY – To evaluate process performance, determine pre- and post-treatment requirements, estimate waste composition, and evaluate membrane cleaning requirements, the composition of the raw water must be well characterized. Both average composition and temporal (especially seasonal) variations in composition are important; and characterization must include not only the constituents targeted for removal, but also other substances that might significantly affect system performance, pre- or post-treatment requirements, the quality of the finished water, and waste disposal. Constituents of interest, in addition to the contaminants to be removed, include: pH, alkalinity, turbidity (or size-distributed particle counts), organic matter, color, coliforms, protozoan cysts, major anions and cations, iron and manganese, and dissolved gases. Seasonal changes in water

temperature must also be well characterized. For RO and NF processes, conductivity, total dissolved solids, and the concentrations of silica, barium, strontium, radionuclides, nutrients, and boron need to be known so that osmotic pressure, scaling potential, and waste composition can be properly evaluated.

2. MEMBRANE TYPE, CONFIGURATION, NUMBER AND ARRANGEMENT

- a. Membrane type, composition, driving force, and operating pH range
- b. Membrane configuration (e.g., spiral wound or hollow fine-fiber) and flow pattern (e.g., cross-flow or dead-end flow)
- c. Number of elements in each module, number of modules per bank, number and arrangement of banks and stages, flow schematics (including capacity and location of feed pumps, recirculation pumps, and backwash pumps), and operating pressure of each stage
- d. System redundancy (number of modules available to achieve the design flow rate when one or more groups of modules is out of service for cleaning, repair, or modification; and redundancy of other critical system components, including valves, air supply and controls)

3. PROCESS OPERATING CONDITIONS

- a. Flow rates of the feed water, product water, and concentrate
- b. Applied pressure, transmembrane pressure, osmotic pressure (if applicable), and pressure drop across each stage and across the entire membrane system
- c. Mode of operation (e.g., constant flux or constant pressure)
- d. Minimum water temperature, maximum water demand, and the minimum net membrane water flux required to meet the demand during each month or season, taking into consideration the strong influence of temperature on water flux for a system operating at a given pressure
- e. Operating pH and means of adjustment
- f. Recirculation rate for cross-flow membranes

4. PROCESS PERFORMANCE – The ability of the process to reliably meet treatment requirements and performance objectives must be thoroughly evaluated and adequately demonstrated.

- a. For each contaminant (or group of contaminants) to be removed by the membrane process, the designer must characterize the concentrations present in the raw water (and feed water, if partial removal is achieved by pretreatment); estimate the average and minimum removal that will be achieved by the membrane process, taking into consideration changes in water temperature, feed water quality, membrane age, operating pressure and other important factors; and provide supporting information to adequately establish the basis for estimates of contaminant removal. For trace constituents, it is especially important to demonstrate that removal results from rejection and not from adsorption on the membrane(s) over a short period of time.
- b. The overall log removal credit for a treatment sequence that includes membranes, and/or the log removal credit for the membrane treatment step by itself, shall be determined by KDHE on a case-by-case basis. When a pilot-plant study will be used to establish log removal credit, KDHE must be contacted prior to the study to establish the protocols to be followed. Pertinent data from pilot- or full-scale installations similar to the one proposed, as well as the results of challenge tests, may be presented in support of a particular level of log removal credit. Pertinent data may include turbidity measurements, microscopic particulate analyses, counts of particles in the appropriate size range, or the results of challenge tests using surrogate particles, surrogate organisms, or live organisms.
- c. In determining log removal credit, consideration will be given not only to the performance of new membranes but also to the performance of aged membranes, the potential for leakage through membrane imperfections and seals, the integrity testing protocols to be employed, the level of instrumentation provided, raw water quality, pre- and post-treatment, and other factors influencing the extent and reliability of pathogen removal.
- d. Regardless of the level of log removal credit allowed, a residual disinfectant will be required to protect the quality of water in the distribution system.
- e. The hydraulic performance of membranes as they age is a key factor in evaluating the economic feasibility of a membrane process. Membrane water flux and product recovery as a function of transmembrane pressure and membrane age should be adequately evaluated; and a reasonable estimate of membrane life (discussed below) is needed to properly estimate operating costs, particularly membrane replacement costs.
- f. KDHE will require post-membrane disinfection to achieve a minimum of 0.5-log inactivation of *Giardia lamblia* and 2-log inactivation of viruses for treatment sequences that employ membranes to treat surface water or GWUL.

5. PRETREATMENT REQUIREMENTS – Membrane performance, cleaning frequency, and useful life depend heavily on the quality of the feed water, which is determined by the quality of the raw water and the pretreatment provided. Acceptable feed water characteristics depend on the type of membrane and operating conditions.
- a. Pretreatment may be needed to remove particulate matter, to remove iron or manganese, to stabilize the water to prevent scale formation, to control microbial growths, to remove chlorine or other oxidants (necessary for certain types of membranes), to adjust pH, to eliminate dissolved gas supersaturation, or to prevent upstream spills of oil, grease, or solvents from entering the membrane system and damaging the membranes. To prevent fouling of RO and NF membranes with elemental sulfur, hydrogen sulfide must be removed by pretreatment, unless an airtight system prevents air from entering the water, in which case hydrogen sulfide may be removed during post-treatment. If hydrogen sulfide is removed using air stripping or degasifiers, the off-gas may require treatment to prevent odor problems.
 - b. In evaluating the stability of the feed water, consideration must be given not only to precipitation of calcium carbonate but also, for RO and NF membranes, to other substances (including silicates, fluoride and sulfate salts) that may precipitate as the concentrate reaches the far ends of the system. Any antiscalant chemicals or solutions (commonly fed prior to NF or RO systems) must be certified for direct or indirect use in the treatment of drinking water (Subsection C.2 of Chapter III). Changes in chemical or solution feed systems will be considered to be changes in treatment and as such must be approved by KDHE.
 - c. A filtration step is normally required ahead of RO or NF; and conventional filtration, MF, UF and cartridge filtration are acceptable for this purpose if compatible with site- and system-specific conditions. At a minimum, cartridge or bag filters should be provided to protect the membranes from excessive amounts of particulate matter; but cartridge or bag filters alone may not be suitable for raw waters having occasionally high levels of turbidity.
 - d. UF and MF membranes are less susceptible to particulate fouling than RO and NF membranes but must still be protected from exposure to large particles or excessive levels of smaller particles. Conventional filtration, presedimentation, roughing filters, and strainers or bag filters able to remove particles in the 100 to 500 μm size range (Bergman, 2005) may be suitable for this purpose, depending on site- and system-specific conditions.
6. POST-TREATMENT REQUIREMENTS – Additional treatment may be required for the product stream, including degasification (for carbon dioxide or hydrogen sulfide removal), alkali addition (for pH adjustment or alkalinity recovery, i.e., conversion of

carbon dioxide to bicarbonate), hardness addition (for corrosion control), hydrogen sulfide oxidation, chemical stabilization (Section L), control of bacterial growths, and final disinfection before the water enters the distribution system.

7. BYPASS WATER – Membrane systems may bypass a portion of the raw water or feed water around the membrane unit provided that treatment objectives and regulatory limits are met. Such a bypass may be necessary to produce a stable finished water, e.g., for an RO system that demineralizes the product water or an NF system that removes most of the hardness. However, the bypass water must be adequately filtered; and when a membrane process is used to obtain log removal credit, any bypass water must be disinfected using an appropriate means of disinfection.
8. CROSS-CONNECTION CONTROL – Cross-connection control must be incorporated into the design (KAR 28-15-18(f)). Consideration must be given not only to cross-connections between the finished water and non-potable water (e.g., the raw water, the feed water, or the concentrate), but also to any cross-connections that might be formed with chemical solutions and cleaning wastes.
9. MEMBRANE CLEANING – Membrane cleaning procedures are membrane and foulant specific. The manufacturer's recommendations as to cleaning solutions and procedures should ordinarily be followed (and may have to be followed to fulfill the terms of the warranty).
 - a. The cleaning method(s) and chemicals used must be approved by KDHE.
 - b. The components of the membrane cleaning system should be specified, including tanks, mixers, heating elements (if any), filters, pipes, valves, and the associated instrumentation and control systems.
 - c. The cleaning process must be designed and operated in a manner that prevents contamination of the raw water, feed water, and finished water.
 - d. A non-destructive method of assessing the membrane condition (e.g., water flux or transmembrane pressure) should be provided.
 - e. During the design a means of flushing membrane modules with high quality water (e.g., permeate, finished water or raw water, depending on the site-specific issues) after planned or unplanned system shutdowns should be considered.
10. INTEGRITY TESTING – Intact membranes achieve virtually complete removal of pathogens larger than the pore size of the membrane; but pathogen removal can be compromised by membrane imperfections such as, but not limited to, broken lumens, leaking seals, and faulty valves. Therefore, when a membrane process is used to

achieve log removal credit, an integrity testing program having direct and indirect integrity testing components is required to verify that the membranes are intact (40 CFR 141.719(b)). Indirect integrity testing must consist of continuously monitoring the turbidity in the effluent from each membrane bank with an appropriately ranged turbidimeter, regardless of the number of banks or arrays employed. Indirect integrity testing based on other water quality parameters, such as conductivity, will be considered for RO and NF membrane systems where turbidity is removed during pretreatment and is therefore not a suitable parameter for monitoring process performance. Off-line direct integrity testing must be performed at least once per day on each bank and the method used must be sensitive enough to verify the removal credit awarded by KDHE. Direct integrity testing methods include the air-pressure (vacuum) decay test, the diffusive airflow test, the water displacement test, and various marker-based integrity tests (USEPA, 2005). The integrity testing program must be approved by KDHE.

11. USEFUL LIFE OF MEMBRANES – Membrane life and replacement costs must be considered in assessing the overall cost of operating the treatment facility. Factors to consider in estimating membrane life include raw water quality, experience with same or similar membranes (especially when treating the same or similar water), the frequency and effectiveness of cleaning, membrane performance requirements (in regard to both water flux and contaminant removal), and the supplier's performance guarantees. The proposed design should include recommended criteria for membrane replacement and a projected membrane replacement schedule.
12. WASTE VOLUME, COMPOSITION, AND DISPOSAL – Wastes generated by membrane systems include pretreatment wastes, membrane concentrate, cleaning wastes, and post-treatment wastes. Reasonable efforts should be made to minimize waste production without compromising the performance of the system. The system design must provide for management of all such wastes in compliance with KDHE requirements. Each waste stream must be fully characterized through appropriate analyses or modeling, and alternate disposal options must be fully evaluated. Potential disposal options include land application, surface water discharge, injection wells, evaporation (in ponds or using evaporators), and discharge to a wastewater treatment plant.
13. INSTRUMENTATION AND CONTROL – A minimum level of instrumentation and control is required to ensure fail-safe operation, to avoid potential damage to the membranes and pumps, and to prevent non-potable water from entering the distribution system. Instrumentation should include appropriate sensors, alarms, or other indicators of changes in finished water quality or in operating conditions (e.g., inadequate feed water quality, pressure or flow rate) that could potentially impair membrane performance or compromise finished water quality. Systems should be designed to automatically shut down when necessary to prevent damage to the system or introduction of non-potable water into the distribution system. Regarding RO, the system designer should consider whether a permeate drawback tank is needed to

prevent damage following feed pump shutdown. The manufacturer should be consulted regarding conditions for the specific project and potential risk of membrane damage. The instrumentation and control system should include an appropriate level of redundancy.

14. OPERATOR TRAINING AND START-UP – The ability to obtain qualified operators must be evaluated when selecting any treatment process, including membrane processes. The necessary operator training shall be provided prior to plant start-up.

T. FLUORIDATION

Detailed information regarding the design and operation of drinking water fluoridation facilities is available from a number of excellent sources, including manuals and handbooks published by the U.S. Department of Health and Human Services (Reeves, 1986, 1994 and 1999) and AWWA (2004c).

1. REQUIREMENTS – KDHE will approve the fluoridation of a PWSS under the following conditions:
 - a. An application has been submitted to KDHE for permission to fluoridate the water supply by the PWSS.
 - b. Plans and specifications covering the following items have been submitted to and approved by KDHE:
 - 1) Chemical to be used as a source of fluoride;
 - 2) Methods of storing and handling the chemical;
 - 3) Feeding equipment;
 - 4) Point of application;
 - 5) Rate of flow at point of application and flow characteristics;
 - 6) Automatic controls;
 - 7) Safety precautions; and
 - 8) Laboratory controls and equipment to be used for determination of dosage and fluoride content of water.
 - c. A copy of an ordinance from a city or a resolution from a rural water district, authorizing fluoridation of the water supply, must be submitted to KDHE.

- d. The owner of the public water supply system must provide to KDHE a written statement designating the operator or operators in responsible charge of the system or facility, or both, whose operator certification is recognized under KAR 28-16-36 as being Class II or higher.

2. **APPLICATION PRINCIPLES AND CRITERIA** – The following general principles will be used in promotion and administration of the program by KDHE.

- a. No fluoridation project should be undertaken without the full cooperation and approval of the city administration (or the rural water district board), the water department, and the local health department, as well as KDHE.
- b. In considering an application for approval of fluoridation, KDHE will consider the qualifications of the public water supply system's operators to perform the control and maintenance operations required.
- c. Chemical forms of fluoride and corresponding methods of feeding are listed in Table V-4. The addition of sodium fluoride, sodium silicofluoride, or hydrofluorosilicic acid constitutes the practice of chemical addition in the production of drinking water and as such shall conform to applicable AWWA standards and NSF International's ANSI/NSF Standard 60, or other equivalent (Subsection C.2 of Chapter III). Other types of fluoride compounds must have prior approval by KDHE.

TABLE V-4

FLUORIDE CHEMICAL FORMS AND FEEDING METHODS

Name	Form	Feeder Type	Remarks
Sodium Fluoride	Powder	Saturator	-
Sodium Silicofluoride (Sodium Fluorosilicate)	Powder	Dry	Low Solubility
Hydrofluorosilicic Acid (Fluorosilicic Acid)	Liquid	Solution	Corrosive

- d. Fluoride chemicals should be isolated from other chemicals to prevent contamination and mixing with other potentially reactive chemicals. Compounds shall be stored in covered or unopened shipping containers and should be stored inside a building. Unsealed storage units for

hydrofluorosilicic acid should be vented to the atmosphere at a point outside the building. Bags, fiber drums, and steel drums should be stored on pallets.

- e. When other chemicals are being fed, chemical compatibility must be considered. Fluoride compounds shall not be added before or during lime-soda ash or ion-exchange softening. Whenever possible, fluoride should be added after filtration. In surface water plants, the ideal location for fluoride addition is usually in the water line from the filters to the clearwell for constant rate filters, but this may not be the case for declining rate filters. In the latter case, if the fluoridation system cannot be flow paced by the filtered water flow rate, the addition may need to be at the high service pump station (ahead of the entry point sampling tap).

If the first customer's service line is located less than 100 ft. (30.5 m) from the fluoride point of application and there is no storage tank between the two points, an in-line mixer or a small mixing tank should be installed in the water line exiting the plant to ensure complete mixing.

For groundwater, the fluoride point of application should be far enough upstream of the entry point sampling tap to ensure complete mixing prior to the treated water entering the distribution system. In the absence of an adequate length of pipe to ensure complete mixing prior to the entry point sampling tap an in-line static mixer may be installed in the discharge pipe between the fluoride point of application and the entry point sampling tap to ensure complete mixing.

- f. Water used for sodium fluoride dissolution shall be softened if its hardness exceeds 75 mg/L as calcium carbonate, and a sediment filter should be installed in the make-up water line.
- g. Scales, loss-of-weight recorders or liquid level indicators, as appropriate, shall be accurate to within 5 percent of the average daily change in reading for the chemical feeders.
- h. Feeding equipment must be accurate within 5 percent, and facilities must be provided for accurately weighing the amount of chemical used. Solution feeders must be of the positive displacement type with a stroke rate of not less than 20 strokes per minute and must be provided with an accurate means for measuring the water used in making up the solution, except where hydrofluosilicic acid is fed directly. Where the point of application of hydrofluorosilicic acid is to be in a horizontal pipe, it shall be in the lower half of the pipe.

The maximum design operating pressure of the feed pump should be at least one-third more than the expected operating pressure at the fluoride point of application.

Selection of the feed pump capacity so that the discharge rate is 30 to 70% of the maximum is important. If the pump operates at either extreme of the operating range the operator will have difficulty in matching flow changes. More importantly, oversized pumps should not be used because they increase the risk of a serious overfeeding event.

Metering pumps should be located on a shelf above the carboy, day tank, or solution container, but not more than 4 ft. (1.2 m) higher than the lowest normal level of liquid. A flooded suction line is not recommended for water fluoridation.

- i. Fluoride solutions shall not be applied at a point of negative pressure.
- j. The electrical outlet used for the fluoride feed pump should have a nonstandard receptacle and its electrical circuit shall be interconnected with the electrical circuit of the well or service pump.
- k. Anti-siphon devices shall be provided for all fluoride feed and dilution water lines. Two anti-siphon devices should be used on each feed line, one on the discharge side of the pump head and the other at the fluoride injection point. The dilution water pipe shall terminate at least two pipe diameters above the solution tank.
- l. Saturators should be of the upflow type and be provided with a meter and backflow protection on the make-up water line. The minimum depth of sodium fluoride in a saturator should be 12 inches (30.5 cm), and this depth should be clearly marked on the outside of the container. A maximum fill line should also be used, since the saturator should never be filled to the point that undissolved chemical is drawn into the pump suction line. Only granular sodium fluoride should be used in saturators, since powdered and very fine forms can cause plugging problems.
- m. A properly sized totalizing water meter is required in the water line to a saturator for all types of saturators as part of assuring that the addition of fluoride will be in proportion to the treated water flow rate. Since saturator make-up flows are very low, this typically requires a small (0.5 to 0.63 inch or 1.3 to 1.6 cm) positive displacement totalizing meter.
- n. Entrained air has a tendency to come out of solution forming bubbles in the feed lines. The air bubbles can interfere with the feed and should be bled from the lines whenever they appear.

- o. Secondary control systems for fluoride chemical feed devices may be required by KDHE as a means of reducing the possibility for overfeed. These may include flow or pressure switches or other devices.
- p. Special precautions must be taken to protect operators against possible injury from concentrated chemicals. A facial respirator with a rubber face-to-mask seal, rubber apron, and rubber gloves are needed, and if hydrofluorosilicic acid is used then splash-proof goggles, a full face shield and rubber boots are also needed. Acid systems should also have flushing water at the place where carboys are handled. Operators must be fully instructed in the proper handling of fluoride chemicals. An eye washer and an emergency shower should be provided.
- q. Provisions must be made for the transfer of dry fluoride compounds from shipping containers to storage bins or hoppers in such a way as to minimize the quantity of fluoride dust that may enter the room in which the equipment is installed. The enclosure shall be provided with an exhaust fan that places the hopper under a negative pressure. Air exhausted from fluoride handling equipment shall discharge through a dust filter to the outside of the building.

Provisions shall be made for disposing of empty bags, drums, or barrels in a manner that will minimize exposure to fluoride dusts. The best practice is to thoroughly rinse all empty containers with water until they are fluoride-free.

- r. Suitable laboratory space and equipment must be provided for the determination of the fluoride content of the water. Two commonly employed methods, the SPADNS (colorimetric) method and the ion-selective electrode method, are described in *Standard Methods* (APHA *et al.*, 2005). The SPADNS method, which employs a spectrophotometer, is often the best choice for small PWSSs. However, this method may require a preliminary distillation step should interfering ions be present at excessive levels. Testing laboratories and larger water plants typically use the electrode method mainly because of the ease of running a large number of samples and its greater tolerance of interferences. Operators appropriately designated by the PWSS to be in responsible charge of the system or facility must demonstrate their proficiency in performing such tests to KDHE's satisfaction prior to the initiation of fluoridation of the PWSS's water supply.

Immediately upon initiating the addition of fluoride, a PWSS must begin collecting paired samples, as described below, to further demonstrate its proficiency in performing fluoride analysis. Concurrently the PWSS must continue collecting samples and analyzing them for fluoride to demonstrate compliance with the MCL (KAR 28-15a-23) or alternatively the SMCL (40 CFR 143.3) for fluoride.

When a PWSS begins fluoridating, paired samples must be collected at least once per day at each affected entry point sampling tap. One sample of each pair must be submitted to KDHE for fluoride analysis and the other sample is to be analyzed by the PWSS for fluoride. A report summarizing the results of the fluoride analyses performed by the water system must be submitted to KDHE so that KDHE can compare both sets of results. The PWSS must continue to collect paired samples for analysis until such time that KDHE is satisfied with the consistency between the PWSS's results and KDHE's results.

After the PWSS has established its proficiency, it must continue to collect and analyze samples (though not paired samples, unless directed to do so by KDHE) to ensure proper operation and for compliance purposes. Samples collected for operational purposes must be collected at each affected entry point sampling tap on a daily basis and analyzed by the PWSS for fluoride using the method employed during the proficiency demonstrating period.

In order for the fluoride analysis to be meaningful, water samples must be collected after the fluoride has completely mixed with the water to which it is being applied. In some cases, a static mixer may have to be installed in the water line at a location sufficiently upstream of the sampling tap to ensure complete mixing. During sample collection from a sampling tap, the sampling tap must be thoroughly flushed prior to the collection of the sample in order to obtain a sample that is representative of the water in the main (Reeves, 1986). Additional discussion regarding this subject may be found in Subsections D.4.g.4 and D.5.d.6 of Chapter IV.

- s. Daily records shall be kept of the amount of chemicals fed, water pumped, and all fluoride determinations. Quarterly reports of the results of the fluoride analyses performed by the public water supply system must be submitted to KDHE – Bureau of Water, Public Water Supply Section, 1000 SW Jackson St., Suite 420, Topeka, KS 66612-1367.
- t. No fluoridation equipment shall be placed in operation until the installation has been inspected by a representative of KDHE and found to be in conformance with the plans and specifications approved by KDHE.

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CHAPTER VI

WATER STORAGE TANKS

A. PRIMARY DESIGN CONSIDERATIONS

Water storage structures shall be stable, durable, and protective of the quality of the stored water. Construction of uncovered finished water storage reservoirs is prohibited. With the exception of vents and overflows, all piping is to be valved.

1. TYPE OF STORAGE – The choice of underground, ground level, or elevated storage depends on volume requirements, topography, hydraulic grade lines, potential for freezing, aviation hazards, security issues of water transmission and distribution lines, and availability and reliability of backup energy sources.
2. LOCATION
 - a. The bottom of a ground level reservoir or standpipe should be placed at the normal ground surface such that it is at least 1 ft. (0.3 m) above finished grade and at least 1 ft. (0.3 m) above the 100-year flood level. The finished grade of the ground surface shall slope away from the reservoir or standpipe for a distance of at least 10 ft. (3.0 m) in all directions.
 - b. When the bottom of a ground level reservoir or a standpipe must be below normal ground surface, it shall be placed above the groundwater table. At least 50 percent of the water depth should be above grade. Sewers, drains, fuel storage facilities (tanks and lines), standing water, and similar sources of contamination must be kept at least 50 ft. (15 m) from the reservoir. Water main pipe, pressure tested in place to 50 psi (345 kPa) without leakage, may be used for gravity sewers at lesser separations, but no closer than 10 ft. (3.0 m). Provisions for appropriate spill containment must be included in any fuel storage facility design.
 - c. The top of an underground reservoir may be located below the lowest frost line to minimize freeze-thaw effects on the structure. In any case (whether the top is above or below the frost line) the top of an underground reservoir shall be both sloped to facilitate drainage and covered with an impervious membrane to protect it from contamination. Additional measures to protect the reservoir from contamination shall be employed where necessary and as approved.

- d. Water quality and distribution system demand centers should be taken into consideration when selecting locations for finished water storage.
 - e. No treated water storage shall be located beneath the filter pipe gallery.
 - f. Finished water shall not be stored or conveyed in a compartment adjacent to untreated or partially treated water where the two compartments are separated by a single wall.
 - g. Hydropneumatic or pressurized storage tanks shall be located above normal ground surface and be completely housed.
3. MATERIALS – Applicable AWWA Standards should be followed for materials used in water storage facilities. Other materials of construction may be acceptable when properly designed to meet the requirements of this chapter. The use of plastic tanks, translucent in particular, for outdoor storage of drinking water is not recommended.
4. FOUNDATION
- a. Foundations for elevated storage tanks, standpipes, and reservoirs must be designed and constructed to ensure uniform support and minimal structural settlement. Unequal settlement impacts the distribution of stresses in the structure and may cause leakage, buckling, or otherwise impair the structural integrity of the tank, standpipe, or reservoir.
 - b. The ultimate bearing capacity of the soil shall be determined based on sound principles of geotechnical engineering in conjunction with a properly conducted soil investigation by a qualified geotechnical engineer. The design soil-bearing pressure shall be derived from the ultimate bearing capacity by the application of an appropriate factor of safety.
5. SIZING
- a. **BACKWASH WATER SUPPLY STORAGE** – When sizing backwash water supply storage and its delivery, consideration must be given to the backwashing of several filters in rapid succession or the possibility of backwashing two or more filters at a time. The quantity of water required per filter will depend upon the filter backwash rate and the duration of the backwash cycle as described in Chapter V, Subsection J.9. Filter backwash water supply storage for all backwash systems shall be designed as finished water storage and be protected from sources of contamination such as backflow from a filter and cross-connection with a non-potable source.
 - b. **CLEARWELL** – Clearwell (and distribution system) storage shall be sized to relieve the filters from having to meet peak fluctuations in water demand.

- c. **DISTRIBUTION STORAGE** – At a minimum, distribution system storage capacity shall be designed to equalize hourly variations in daily water demand, limit fluctuations in distribution system pressure, and provide reserve storage for fire protection, power outages and other emergencies. (In the absence of meter data, peak hourly flow can be assumed to be equal to twice the maximum daily flow or four times the average daily flow.) The minimum storage capacity for systems not providing fire protection e.g., rural water districts, may be reduced when the source waters and the treatment facilities have sufficient capacity with standby power capability to supplement system peak demands. For either situation, the system shall have the capability of replenishing its distribution system storage capacity each night and during low demand periods.

The maximum variation between high and low levels in storage structures providing pressure to a public water supply distribution system should not exceed 40 ft. (12 m). The minimum pressure in the distribution system shall be 20 psi (140 kPa) at ground level at all points in the distribution system under all flow conditions (KAR 28-15-18(e)). The normal working pressure should be approximately 60 psi (410 kPa). Pressure-reducing devices should be provided on mains in the distribution system or on individual service lines when static pressures exceed 100 psi (690 kPa). In some cases, establishing different distribution system pressure zones may be the most appropriate way to meet these requirements. Additional discussion regarding distribution system pressure may be found in Subsections A.1 and B.5 of Chapter VIII.

- d. **PRESSURE TANKS** – Hydropneumatic tanks, when provided as the only means of storage, are acceptable only in very small water supply systems. Ground or elevated storage should be provided when serving more than 150 living units. Pressure tank storage is not to be considered as being available for fire protection services. Pressure tanks shall meet applicable ASME requirements or equivalent requirements of state and local laws and regulations for the construction and installation of unfired pressure vessels (ASME, 2004).

Small PWSSs using wells and pressure storage tanks should make the gross volume of the hydropneumatic tank at least 10 to 15 times the capacity of the largest pump (in gpm). Sizing of hydropneumatic tanks must also consider the need for adequate disinfectant contact time.

The proper air to liquid volume ratio should be determined to prevent excessive pump cycling for the normal operating pressure range of 40 to 60 psi (280 to 410 kPa). Well and pump capacities should be at least 10 times the average daily demand.

A minimum of two wells and two pumps shall be provided for a pressure storage tank system. A duplicate pressure tank or bypass piping is required to facilitate maintenance of the hydropneumatic system.

- e. PRESSURIZED SYSTEMS – Pump pressurized distribution systems without storage will not be approved.

- 6. ROOF AND SIDEWALL – All finished water storage structures shall have suitable watertight roofs or covers that exclude birds, animals, insects, and excessive dust. The roof or cover of the storage structure shall be watertight with no openings except properly constructed vents, manways, overflows, risers, drains, pump mountings, control ports, or piping for inflow and outflow (KAR 28-15-18(g)).

- a. All pipes running through the roof or sidewall of a finished water storage structure shall be welded or properly gasketed where the tank is metal, or connected to standard wall castings which were poured in place during the forming of a concrete structure. These wall castings should have seepage rings imbedded in the concrete. Raw water lines or drains shall not pass through a finished water structure.
- b. Openings in a storage structure roof or top, designed to accommodate control apparatus or pump columns, shall be curbed and sleeved with proper additional shielding to prevent the access of surface water to the structure. Where a cover is provided, a hasp and lock or other equivalent means of securing the cover shall be provided.
- c. Valves and controls shall be located outside the storage structure so that valve stems and similar projections will not pass through the roof or top of the reservoir and the reservoir will not be subject to contamination by surface water.
- d. The roof or cover for the storage structure shall be well drained, but downspout pipes shall not enter or pass through the reservoir. Parapets, or similar construction which would tend to hold water and snow on the roof, will not be approved unless adequate waterproofing and drainage are provided. The roof of a concrete reservoir with earthen cover shall be both sloped to facilitate drainage and covered by an impervious membrane to protect it from contamination. Additional measures to protect the reservoir from contamination shall be employed where necessary and as approved.
- e. All indoor finished water storage structures shall have an integral roof or cover as outlined above. Partially or fully open finished water storage structures located within a partially or fully enclosed building structure will not be approved.

- f. Storage reservoirs with pre-cast concrete roof structures will not be approved.
 - g. Storage structure condensate collection system drain lines shall be drained to ground level. Direct or indirect drainage of a condensate collection system to an overflow will not be approved.
7. OVERFLOW – All water storage structures shall be provided with an overflow that is brought down to an elevation between 1 and 2 ft. (0.3 and 0.6 m) above the ground surface and discharges over a drainage inlet structure or a splash plate. No overflow may be connected directly to any type of a sewer or a storm drain, drain piping or drain structure. All overflow pipes shall be located so that any discharge is visible.
- a. When an internal overflow pipe is used on an elevated tank, it should be located in the access tube. For vertical drops on the other types of storage facilities, the overflow pipe should be located on the outside of the structure.
 - b. The overflow for a ground level or elevated storage structure shall open downward and be screened with a non-corrodible screen with 0.25 inch (0.64 cm) openings installed within the pipe at a location least susceptible to damage by vandalism, or the discharge of the overflow pipe shall be fitted with a self-closing flap gate having an integral screen.
 - c. The overflow pipe shall be of sufficient diameter to permit the waste of water in excess of the filling rate.
8. VENTS – Finished water storage structures shall be vented. Overflows shall not be considered as vents nor should they be connected to vent piping. Open construction between the sidewall and roof will not be approved. In general, vents shall incorporate a fail-safe feature such as a screen that lifts when the tank empties at a rapid rate so that air can enter the vent pipe unrestricted. In addition, they shall prevent the entrance of surface water and rainwater, and exclude birds, animals, insects, rain, and dust by vent caps or other means. Vents for elevated storage tanks and standpipes shall be screened with 16-mesh non-corrodible screen. Vent construction for ground level storage structures should consist of an inverted “U” having an opening that is 2 to 3 ft. (0.6 to 0.9 m) above the roof or sod and is covered with 24-mesh non-corrodible screen installed within the pipe at a location least susceptible to vandalism.
9. LEVEL CONTROLS – Adequate controls shall be provided to maintain levels in distribution system storage structures. Pumps should be controlled from tank levels with the signal transmitted by telemetering equipment. Altitude valves or equivalent devices are desirable when multiple elevated tanks exist. Overflow and low-level warning or alarms should be located where they will be under responsible surveillance 24 hours a day.

B. OTHER CONSIDERATIONS

1. ACCESS – Finished water storage structures shall be designed for convenient access to the tank interior for cleaning, maintenance, and sampling. Manways above the water line on ground level and elevated storage tanks shall be framed at least 4 inches (10.2 cm) and preferably 6 inches (15.2 cm) above the surface of the tank roof at the opening. Manways on underground or earth-covered storage structures should be elevated 2 to 3 ft. (0.6 to 0.9 m) above the top of the structure or covering sod, whichever is higher. Manways shall be fitted with a solid watertight cover that overlaps the framed opening, extends down around the frame at least 2 inches (5.1 cm), is hinged at one side, and has a locking device. Manways below water line on ground level storage tanks should be located 2 to 3 ft. (0.6 to 0.9 m) above the elevation of the tank bottom. Manways shall be fitted with a solid watertight cover which overlaps the framed opening and overlaps the frame at least 2 inches (5.1 cm), be hinged at one side, and have a locking device. All entryways shall be gasketed to be watertight.
2. BASINS AND WET WELLS – Post-filtration disinfection contact basins, receiving basins, transfer wells and pump wet wells for finished water shall be designed as finished water storage structures.
3. DRAIN – Storage structures that provide pressure directly to the distribution system shall be designed so they can be isolated from the distribution system and drained for cleaning or maintenance without loss of pressure in the distribution system. The drain shall discharge to the ground surface with no direct connection to a sewer or storm drain.
4. FIRE PROTECTION – Elevated storage facilities shall have adequate clearance from buildings or other combustibles, or shall be fire-proofed.
5. FREEZING – All finished water storage structures and their appurtenances, especially the riser pipes, overflows, and vents shall be designed to prevent freezing which will interfere with proper functioning. Consideration should be given to heating and/or insulation of exposed pipes and valves.
6. GRADING – The area surrounding a ground level structure shall be graded to prevent surface water from standing within 50 ft. (15 m) of the structure.
7. INTERNAL CATWALK – Walkways over finished water in a storage structure will not be approved by KDHE.
8. PAINTING AND/OR CATHODIC PROTECTION – Proper protection shall be given to metal surfaces by paints or other protective coatings, by cathodic protective devices, or by both. All interior coatings or paints must be certified as meeting NSF International's ANSI/NSF standards for potable water, or equivalent, applied in

conformance with the manufacturer's recommendations, and protect public health and the environment (KAR 28-15-18(h)). After curing, the coating or coating system shall not transfer any toxic or taste and odor causing substances to the water. Prior to placing a tank in service, an analysis for VOCs is advisable to establish that the coating is properly cured.

Coating the interior of a previously uncoated storage tank with a wax coating will not be approved. Recoating the interior of a storage tank previously coated with a wax system is discouraged. However, when recoating the interior of a previously coated storage tank with a wax system is unavoidable, the old wax coating must be completely removed prior to the application of the new wax coating.

Cathodic protection should be designed and installed by competent technical personnel. A maintenance contract should be provided.

9. SAFETY – The safety of employees shall be considered in the design of storage structures. As a minimum, such structures and their appurtenances should conform to all pertinent laws, including local regulations. Ladders, ladder guards, balcony railings, and located entrance hatches shall be provided where applicable. Elevated tanks with riser pipes over 8 inches (20.3 cm) in diameter shall have protective bars over the riser openings inside the tank. Railings or handholds shall be provided on elevated tanks where persons must transfer from the access tube to the water compartment.
10. SECURITY – Fencing, locking devices on access manways, and other necessary precautions shall be provided to deter trespassing, vandalism and sabotage.
11. SILT PROTECTION – Discharge pipes shall be located to prevent silt from entering the distribution system. Removable silt stops are required.
12. DISINFECTION
 - a. RE-CHLORINATION – Re-chlorination will be required if the disinfectant residual in the distribution system must be augmented in order to maintain an acceptable disinfectant residual at the ends of the distribution system. Re-chlorination system designs must be accompanied by calculations and data demonstrating that an adequate disinfectant residual will be maintained at the ends of a public water supply system's distribution system, and also at the ends of the distribution systems of those consecutive public water supply systems which do not re-chlorinate.
 - b. MAINTENANCE AND REPAIR – All new, repaired, or repainted reservoirs must be flushed and disinfected (KAR 28-15-18(d)) according to applicable AWWA Standards before being placed into service with the exception that disinfection by Method 3 of section 4.3 of AWWA Standard C652 is not

allowed. Two or more successive sets of samples, taken at 24-hour intervals, shall indicate microbiologically satisfactory water before the facilities are placed into operation.

Disposal of heavily chlorinated water from tank disinfection processes shall be in accordance with KDHE requirements (Appendix D).

13. PRESSURE TANKS – Each tank shall have an access manway, a drain, and control equipment consisting of pressure gauge, water sight glass, automatic or manual air blow-off, means for adding air, and pressure-operated start/stop controls for the pumps. Where practical, the access manway should be 2 ft. (0.6 m) in diameter.
14. WATER CIRCULATION – Include in all reservoir designs provisions to ensure adequate water circulation. Baffling or placement of inlets and outlets may be employed to promote circulation in underground or ground level reservoirs. Inlets and outlets for these types of reservoirs should be located on opposite sides of the reservoir with the outlets being located near the floor.

While the physical nature of standpipes and elevated storage tanks may limit placement of separate or combined inlets and outlets, their respective geometries in combination with appropriately sized pipe can produce flow velocities that will promote water circulation. In addition, internal distribution piping may be utilized to further promote water circulation.

15. MAINTENANCE/INSPECTION – It is recommended that a maintenance and inspection program for all storage structures be implemented and followed as part of the system's approach to managing and protecting the quality of its drinking water. When possible, at least one other reservoir shall be available for storage during the outage of any one storage structure. Storage structures should be drained, cleaned and inspected every two years.

CHAPTER VII

PUMPING FACILITIES

- A. GENERAL REQUIREMENTS** – Pumping facilities shall be designed to maintain the sanitary quality of pumped water and in such quantities and pressures as necessary. They should not be vulnerable to interruption caused by natural or man-made disturbances. Every effort shall be made to insure the safe and satisfactory operation of the water supply pumping facilities. Additional specific requirements applicable to well pumps and well house pumping installations are provided in Chapter IV.
- B. PUMPING STATIONS**
1. LOCATION – Pump station site considerations should include its location relative to the water resource and point of delivery, availability of utilities and land for future needs, and its sanitary protection. Pump stations shall be located above ground, graded to carry surface water away from the station, and protected from vandalism and unauthorized entry. Station accessibility shall be provided for ease of needed service.
 2. FACILITIES
 - a. Floor elevation must be at least 1 ft. (0.3 m) above the 100-year flood elevation or protected to that elevation. In addition, the elevation of the floor is to be at least 6 inches (15.2 cm) above finished grade. When locating a pump station below ground level cannot be avoided, totally enclosed pumps and motors will be required.
 - b. Provide adequate interior space as needed for the installation of additional units and for the safe servicing of all equipment.
 - c. Building must be of durable construction, fire and weather resistant and have outward opening doors.
 - d. Means for disinfecting all facilities must be provided.
 - e. Floors must drain without impairing the quality of water being handled. All floors shall slope toward a suitable drain at 1/8 inch/foot (1.0 cm/m).
 - f. Provide suitable outlet for drainage from pump glands without discharging onto the floor.

3. SPACE REQUIREMENTS – In planning pump stations, sufficient floor space should be provided for pumps, suction and discharge pipe headers, re-chlorination equipment, proportioning flow controls, and electrical switch-gear. Access to pumps and motors and space for equipment needed for installation, removal, and servicing of pumps and auxiliaries should also be considered.
4. EQUIPMENT SERVICING – Pump stations shall be provided with crane-ways, hoist beams, eyebolts, or other adequate facilities for servicing or removal of pumps, motors, or other heavy equipment; openings in floors, roofs or elsewhere as needed for removal of heavy or bulky equipment; and a convenient tool board, or other facilities as needed, for proper maintenance of the equipment.
5. SANITARY AND OTHER CONVENIENCES – Except for small automatic stations or where such facilities are otherwise available, all pumping stations should be provided with potable water, lavatory, and toilet facilities. Plumbing should be so installed as to prevent contamination of a PWSS.
6. STAIRWAYS AND LADDERS – Stairways or ladders shall be provided between all floors and in pits or compartments which must be entered from another level, and they shall have handrails on both sides and treads of non-slip material. Stairs are preferred in areas where there is frequent traffic or where supplies are transported by hand. They should have risers not exceeding 9 inches (22.9 cm) and treads wide enough for safety.
7. HEATING – Provisions shall be made for adequate heating for the comfort of the operator and the safe and efficient operation of the equipment. Pump houses not occupied by personnel should be sufficiently heated to prevent freezing water or chemical solutions in equipment or treatment processes.
8. VENTILATION – Adequate ventilation shall be provided for all pumping stations. Forced ventilation of at least six changes of air per hour shall be provided for all rooms, compartments, pits, or other enclosures below grade level, and for any area where an unsafe atmosphere may develop or where excessive heat may build up.
9. DEHUMIDIFICATION – Dehumidification should be provided in areas where excess moisture could cause safety hazards or damage to equipment.
10. LIGHTING – Pump stations shall be adequately lighted. All electrical work should conform to the requirements of State and local codes.
11. SUCTION WELLS – Wells shall be watertight, have sloped floors to permit removal of water and entrained solids, and be covered or otherwise protected against contamination.

C. PUMPS

1. TYPES – Single and multistage centrifugal pumps are almost universally used for water booster service facilities or high service pump stations. Well pumps include deep well vertical turbine, submersible, propeller and mixed flow, jet, air lift, rotary, or reciprocating pumps.
2. SELECTION CRITERIA
 - a. CAPACITY – Capacity requirements are determined by the peak hourly demand on the system served by the pump station, and the range of present and future operating conditions anticipated. A pump should be selected which will operate alone or in parallel with other pump units when required, and at maximum operating efficiency over the range of head and flow conditions.
 - b. CHARACTERISTIC CURVES – Each centrifugal pump has its own characteristic curves and the pump must fit into the system and be able to operate within its head and flow constraints. If pumps cannot be found to fit the requirements at a constant motor speed, then pumps with variable-speed drives are advisable.

It is good practice to select a pump with an impeller that is smaller in diameter than the maximum impeller size for that pump so that a larger impeller can be installed when water demands increase. It may also be desirable to oversize the motor in the original installation as a provision for the future use of a larger impeller.
 - c. EFFICIENCY – Do not select a pump on the basis of a very high efficiency at a single design or specification point. Rather the selection should be made on the best average efficiency over the entire range of conditions under which the pump will operate including parallel operation with other pump units.
 - d. SPEED – The speed should be selected so as not to exceed that which the pump type can handle. Upper limits of speed with respect to capacity, head, and suction conditions should not be exceeded in order to avoid cavitation.
3. NUMBER OF PUMPS – At least two pumping units shall be provided for water booster service facilities or high service pump stations. With any pump out of service, the remaining pump or pumps shall be capable of meeting the peak demand of the system against the required distribution system pressure without dangerous overloading.
4. DESIRABLE OPERATING CONDITIONS – The NPSH of proposed pump installation should be greater than the required NPSH of the pump under all operating

conditions. Suction lift should be avoided if possible or be within allowable limits, preferably less than 15 ft. (4.6 m). Provisions should be made for pump priming should suction lift be necessary.

Continuous pumping is preferable to frequent stopping and starting. The selected pump capacity should minimize the number of on-off cycles. The minimum period of operation should not be less than 15 minutes.

5. PUMP SUCTION AND PRIMING – Provisions to prime pumps are necessary when suction lift is required. Priming water shall not be of lesser sanitary quality than that of the water being pumped. Means shall be provided to prevent back siphonage. Centrifugal pumps may be provided with an air, steam, or water operated ejector connected to the top of the pump case. When an air-operated ejector is used, the screened intake should draw clean air from a point at least 10 ft. (3.0 m) above the ground or other source of contamination, unless the air intake is fitted with an approved filtering apparatus. Vacuum priming may be used.

The suction piping should be as short and direct as possible and sized such that the maximum flow velocity is less than 4 ft/sec (1.2 m/s). The suction pipe should be larger than the discharge pipe. Pipe bends that unevenly distribute flow across the suction of multiple pumps should not be used. Suction piping should slope upward from the source to the pump and be airtight.

6. DRIVES – Pumps may be driven by electric motors, steam turbines, or diesel, gas, or gasoline engines. Drives may be direct or by power transmission. Properly designed belt or chain drives are acceptable. Right angle gear drives are useful, particularly for connecting power from two sources such as an electric motor drive and a standby engine drive, so that either can be selected through a clutch arrangement.
7. POWER REQUIREMENTS – Power units shall be sized to operate without overload under all possible combinations of flow and head from zero to maximum flow at any head from zero to shut-off head.
8. WELL PUMP SELECTION AND INSTALLATION – Some factors to be considered in selecting a pump for a particular well installation are: capacity, depth of well, pumping level, inside diameter of well, condition of bore, abrasive properties of water (e.g., sand), total head, type of power available, and costs.
9. BOOSTER OR HIGH SERVICE PUMPS – Booster or high service pumps may be used to increase pressures in parts of a water distribution system by taking suction from a main or reservoir in one part of the system at low pressure and discharging it into another part of the system, a storage reservoir, or elevated tank at a higher pressure. When discharging into a reservoir or tank, constant speed centrifugal pumps may be used. Individual home booster pumps shall not be allowed for any individual service from the PWS main.

Booster or high service pumps shall be located or controlled so that they will not produce negative pressure in their suction lines. The intake pressure must be at least 20 psi (140 kPa) when the pump is in normal operation. The automatic cutoff pressure must be at least 10 psi (70 kPa) in the suction line. The automatic or remote control devices shall have a range between the start and cutoff pressure that will prevent excessive cycling, and they should be readily accessible for servicing and repairs. A bypass is required and disinfection facilities may be required.

D. APPURTENANCES

1. VALVES – Pumps should be adequately valved to permit operation, maintenance, removal and repair of the equipment while the rest of the system remains in operation. If foot valves are necessary they should have a net valve area of at least two-and-one-half times the area of the suction pipe, and they should be screened. Each pump should have a positive acting check valve on the discharge side between the pump and shutoff valve.
2. PIPING – In general piping should:
 - a. Be designed so that the friction losses will be minimized;
 - b. Not be subject to contamination;
 - c. Be sloped in one direction to drains;
 - d. Have adequate cleanouts;
 - e. Have watertight joints;
 - f. Be protected against surge or water hammer by:
 - 1) Slow valve closure;
 - 2) Surge tank with free water surface;
 - 3) Air chamber;
 - 4) Surge suppressor;
 - 5) Surge relief valve; and
 - 6) Pump reversal.

- g. Be such that each pump has an individual suction line or the lines should be manifolded so that they will insure similar hydraulic and operating conditions; and
 - h. Be arranged for minimum interruption of service due to any one piping break.
3. GAUGES AND METERS – Each booster or high service pump should have a standard pressure gauge on its discharge line, a compound gauge on its suction line, and recording gauges. Each pump or group of pumps should have means for measuring the discharge. All booster or high service pumping stations should have indicating, totalizing, and recording meters for the total water pumped.
 4. WATER SEALS – Water seals should not be supplied with water of a lesser sanitary quality than that of the water being pumped. Where pumps are sealed with potable water and are pumping water of lesser sanitary quality, the seal should be provided with a break tank open to atmospheric pressure and have an air gap, between feeder line and the spill line of the tank, of at least 6 inches (15.2 cm) or two pipe diameters, whichever is greater.
 5. CONTROLS – Pumps, their prime movers and accessories should be controlled in such a manner that they will operate at rated capacity without dangerous overload. Where two or more pumps are installed, provision should be made for proper alternation. Provision should be made to prevent operation of the pump during the backspin cycle. Electrical controls should be located above grade. Equipment shall be provided or other arrangements made to prevent surge pressures from activating controls that switch pumps on or activate other equipment outside the normal design cycle of operation.
 6. AUTOMATIC AND REMOTE CONTROLLED STATIONS – All automatic stations should be provided with automatic signaling apparatus which report when the station is out of service. All remote controlled stations should be electrically operated and controlled, and have signaling apparatus of proven performance. Installation of electrical equipment shall conform to state and local codes.
 7. STANDBY POWER – To ensure continuous service when the primary power has been interrupted, a power supply from at least two independent sources or a standby/auxiliary source shall be provided. Fuel storage facilities and fuel lines must be designed to protect the water supply from contamination when standby power is provided by on-site generators or engines. Preferred fuels are natural or bottled gas.
 8. WATER PRELUBRICATION – When automatic prelubrication of pump bearings is necessary and an auxiliary power supply is provided, the prelubrication line shall be fitted with a bypass valve to bypass around the automatic control so that the bearings can, if necessary, be lubricated manually before the pump is started. Alternatively, the prelubrication controls shall be wired to the auxiliary power supply.

CHAPTER VIII

DISTRIBUTION SYSTEMS

A. BASIC CONSIDERATIONS

1. QUANTITY AND PRESSURE – Water distribution systems shall be designed, constructed, and operated to provide an adequate supply of water at a pressure of not less than 20 psi (140 kPa) at ground level at all points in the distribution system under all flow conditions except extraordinary conditions including unusual peak fire flow demand and major distribution system breaks (KAR 28-15-18(e)). The normal working pressure in the distribution system should be in the range of 60 to 80 psi (410 kPa to 550 kPa). It is not uncommon for systems to have a normal working pressure in the range of 90 to 110 psi (620 to 760 kPa) (AWWA, 2005b). Pressures in excess of 100 psi (690 kPa) may be necessary because of fire protection requirements, head loss associated with backflow prevention devices, or the need to serve low-lying areas. In the latter case, pressure reducing valves may be used to lower the pressure in these areas so long as their presence and operation do not conflict with fire protection requirements. Variation in pressure at any single point in the distribution system should normally not exceed 20 to 30 psi (140 kPa to 210 kPa) (AWWA, 2005b). Additional guidance regarding distribution system design and working pressures may be found in the AWWA Manual of Water Supply Practices M32 (AWWA, 2005b).

Distribution and transmission mains for both municipalities and rural water districts should be sized to carry peak hourly flow plus fire flow; however, rural water districts commonly size to carry peak hourly flow only. In general, water treatment plants are designed to meet the maximum day demand, while the distribution system facilities, i.e., piping and storage, are designed to meet the maximum hourly flow demand plus fire flow in order to maintain adequate pressure during periods of high demand. Rural water districts typically employ proportionally larger storage facilities to meet fire flows and to reduce the size and cost of transmission lines, i.e., by sizing long transmission lines to carry maximum daily flow, with storage used to supply the maximum hourly flow to a particular service area. In the absence of meter data, peak hourly flow can be assumed to be equal to twice the maximum daily flow or four times the average daily flow. Methods for estimating peak consumer demand are provided in the AWWA Manual of Water Supply Practices M22 (AWWA, 2003).

The minimum diameter of water mains for providing fire protection and serving fire hydrants shall be 6 inches (15.2 cm). Larger size mains may be necessary to provide sufficient fire flow while maintaining the minimum residual pressure. When fire protection is to be provided, system designs shall be in accordance with the PWSS's

designated procedure for determining fire flow requirements. One of the more widely utilized methods for calculating fire flow requirements was developed by ISO, formerly known as the Insurance Services Office, Inc. Their methods (ISO, 2003) and others are evaluated in the AWWA Manual of Water Supply Practices M31 (AWWA, 1998).

2. QUALITY – The safety and palatability of potable water should not be degraded in any manner while flowing through the distribution system. KAR 28-15a establishes water quality, analytical methods, and monitoring requirements for drinking water.
3. GENERAL PIPELINE LOCATION
 - a. Use available data on topography, soil, geology, and climate.
 - b. Tunneling should be considered only when it is economically justified and when there are no feasible alternate routes.
 - c. Select shortest feasible route from intake to delivery.
 - d. Make lines accessible for repairs and future construction.
 - e. Avoid rough or difficult terrain.
 - f. Special engineering evaluations are warranted where disasters such as landslides, 100-year floods, or other hazards are likely to cause breakage or outage.
 - g. The use of plastic coated metal strips, tracer wire or other type of conductor should be considered, particularly where non-conductive pipe is utilized. Surface markers such as signs or posts should be appropriately located irrespective of pipe material.
 - h. KDHE strongly recommends that up-to-date records of the installation of water lines and related appurtenances be maintained through the use of accurate “as built” drawings or a geographical information system (GIS) capable of storing, analyzing and managing spatial data and associated attributes. Global positioning data collection should be considered for all new construction for the purpose of accurately locating pipe lines and related appurtenances within the GIS system.

B. PROTECTION CONSIDERATIONS

1. SEPARATION OF WATER MAINS AND SEWERS

a. GRAVITY SANITARY SEWERS

- 1) Parallel Placements – When potable water pipes and gravity sanitary sewers are laid parallel to each other, the horizontal distance between them shall not be less than 10 ft. (3.0 m). The distance of separation shall be measured from edge to edge. The laying of water pipes and sanitary sewers shall be in separate trenches with undisturbed earth between them. Where it is not practical to maintain a 10 ft. (3.0 m) separation, KDHE will consider proposals providing equivalent protection by other methods on a case-by-case basis, if supported by data from the design engineer. Equivalent protection may require sanitary sewer construction with one of the following additional protective features: concrete encasement, vacuum sewers, or jointless pipe such as fused HDPE or cured-in-place pipe liner.
- 2) Crossing Placements – When a water pipe and a sanitary sewer cross and the sewer is 2 ft. (0.6 m) or more (clear space) below the water pipe, no special requirements or limitations are provided herein. At all other crossings, the sanitary sewer is to be constructed of one of the following materials (or approved equal) and pressure tested to assure water tightness pursuant to the most recent revision of KDHE's *Minimum Standards of Design of Water Pollution Control Facilities*:
 - a) Ductile iron pipe conforming to ASTM A536 or ANSI/AWWA C151/A21.51 with minimum thickness class 50, and gasketed, push-on, or mechanical joints in conformance with ANSI/AWWA C110/A21.10 or ANSI/AWWA C111/A21.11.
 - b) PVC pipe conforming to ASTM D3034 with minimum wall thickness of SDR41, ASTM F679, or ASTM F794, with gasketed push-on joints in conformance with ASTM D3212.
 - c) Reinforced concrete pipe conforming to ASTM C76 with gasketed joints in conformance with ASTM C361 or ASTM C443.

Joints in the sewer pipe shall be located as far as practical from the intersected water main.

Where a water main is laid across or through an area where there is an existing sanitary sewer, which is not constructed of one of the above specified materials and is 2 ft. (0.6 m) or less below the water pipe, the existing sewer shall be encased in concrete with a minimum thickness of 6 inches (15.2 cm) for a 10 ft. (3.0 m) distance on each side of the crossing or the crossed section of sewer replaced to meet the above specified construction requirements. The above requirements shall also apply where a water main must cross under an existing sanitary sewer. KDHE will consider proposals providing equivalent protection by other means on a case-by-case basis, if supported by data from the design engineer.

When a water main and a sanitary sewer must cross, it is preferred that the water main cross over the sanitary sewer, regardless of whether the sanitary sewer is new or existing.

Special provisions may be required to ensure adequate structural support for, and to maintain minimum pipe-to-pipe clearances between, a water main and a sanitary sewer at a water main and sanitary sewer crossing.

- b. SEWER CONNECTIONS – There are to be no physical connections between any parts of a potable water system and building sewers, sanitary sewers, or wastewater treatment facilities by means of which it would be possible for sewage, even under exceptional circumstances, to reach a well, storage reservoir, or distribution system.
- c. PRESSURE SEWER LINES – When pressure sewer lines (force mains) run parallel to water lines, the separation distance shall be as far as practical, maintaining a minimum horizontal separation distance of at least 10 ft. (3.0 m). There shall be at least a 2 ft. (0.6 m) vertical separation at crossings with the water main always crossing above the sewer force main. Where it is not practical to maintain the required horizontal or vertical separation distance between a water line and a sanitary sewer force main, KDHE will consider proposals providing equivalent protection by other methods on a case-by-case basis, if supported by data from the design engineer.
- d. SEWER MANHOLES – No water pipe shall pass through or come in contact with any part of a sewer manhole. Required horizontal separation distances between water mains and manholes are equivalent to those for water mains and gravity sanitary sewers.
- e. STORM SEWERS – The separation distance between a storm sewer (which is not a combined storm/sanitary sewer) and a water main should be based on geotechnical considerations. Required separation distances between water

mains and combined storm/sanitary sewers are equivalent to those for water mains and gravity sanitary sewers.

- f. DRAINS – Underground drains from fire hydrants, pits, or underground structures in general (valve pits, meter pits, underground pump stations, etc.) shall not be directly connected to sanitary or storm drains.

- 2. SEPARATION OF WATER MAINS AND OTHER POLLUTION SOURCES – It is of the utmost importance that potable water lines be protected from any source of pollution. The following shall pertain to instances where septic tanks, absorption fields, waste stabilization ponds, feedlots, or other sources of pollution are encountered.

- a. A minimum distance of 25 ft. (7.6 m) shall be maintained between all potable water lines and all pollution sources, e.g., septic tanks, septic tank absorption fields, waste stabilization ponds, sewage contamination, wastewater, landfill leachate, and all CAFO facilities.
- b. Under no circumstances shall a water line be extended through an area that is a real or potential source of contamination to the water line or water supply.
- c. Under no conditions shall the encasement of a water line be considered as adequate protection of a water line or a water supply for the purpose of extending the water line through a real or potential source of contamination.

- 3. CROSS CONNECTIONS – There shall be no physical connection between the PWSS and any pipes, pumps, hydrants, tanks, or non-potable waters supplies whereby unsafe water or other contaminating materials may be discharged or drawn into the system. KDHE approval shall be obtained for interconnections between potable water supplies. KDHE does not approve of the interconnection of any public water supply water line with any individual or independent water supply source such as a home well. Neither steam condensate nor cooling water from engine jacket or other heat exchange devices shall be returned to the potable water supply.

KSA 65-171g prohibits the contamination of water (and air) by sewage through direct connection or back siphonage and KAR 28-15-18 (f) requires each PWSS to have a formal cross-connection prevention program. KDHE must approve the program used to accomplish the control. Publications regarding cross-connection control are available from AWWA (2004a), USEPA (2003c), and University of Southern California (1993).

The water purveyor should be aware of any situation requiring an inspection and/or a reinspection necessary to detect hazardous conditions resulting from cross connections. If, in the opinion of the water purveyor, effective measures consistent with the degrees of the hazards created by the cross-connections have not been taken,

then the water purveyor should immediately take such measures as are deemed necessary to ensure that the PWSS is protected from any contamination arising from any of the cross-connections. Appropriate measures may include requiring the installation of a backflow protection device consistent with the degree of hazard or discontinuance of service.

4. LINE CROSSINGS – Special precautions should be taken to prevent possible damage to line crossings.

a. SURFACE WATER CROSSINGS – Surface water crossings, both over and under water, present special problems which should be discussed with KDHE before final plans are prepared. Where the ground has inadequate bearing capacity, pile supports, stringers, or other acceptable methods shall be used. A pipeline crossing of a perennial stream having 50 or more square miles (130 km²) of drainage area above the proposed project site requires a permit from DWR, except for a directionally bored crossing or a crossing consisting of a pipeline non-obstructively attached to an existing bridging structure.

1) Above-Water Crossings – The pipe shall be adequately supported, protected from damage and freezing, and accessible for repair or replacement.

2) Underwater Crossings – Underground pipelines shall be buried at a sufficient depth below streambeds to prevent exposure.

a) On navigable streams, underground pipelines shall be buried at a minimum depth of 7 ft. (2.1 m) beneath the streambed.

b) On all other streams, underground pipelines shall be buried at a minimum depth of 5 ft. (1.5 m) beneath the streambed.

c) When crossing water courses which are greater than 15 ft. (4.6 m) in width,

(1) The pipe should be of special construction, having flexible, restrained or welded watertight joints.

(2) Valves should be provided at both ends of water crossings so that the section can be isolated for testing and repair; the valves should be easily accessible, and not subject to flooding.

Permanent taps or other provisions to allow operators to determine leakage and obtain water samples should be made.

- b. **RAILROAD CROSSING AND MAINS NEAR TRACKS** – where a water main crosses under railroad tracks, all joints lying within 10 ft. (3.0 m) of the rails shall be either mechanical joints with rubber gaskets or pipe with bell joints. Also, local requirements should be investigated. Some railroads require that the water main be enclosed in a culvert, tunnel, or conduit to reduce the effects of vibration, to provide drainage in case of leakage or rupture of the pipe, to reduce damage to the track, and to facilitate repairs.
 - c. **MECHANICAL ENCASEMENT** – Where a water line must be sleeved within a pipe in order to protect the water line, such as at road, railroad, or pipe way crossings, the water line must be sleeved with seamless, jointless pipe of equal or greater mechanical strength for distance of at least 10 ft. (3.0 m) beyond the crossing in both direction, kept separate from the sleeve pipe with plastic spacers or wooden skids, and the annular spaces formed at the ends of the carrier/sleeve pipes must be made watertight with flexible boot type end seals.
5. **PRESSURE** – When static pressures in the distribution system exceed 100 psi (690 kPa), pressure-reducing devices should be considered for mains in the distribution system. Pressure-reducing devices should be provided for individual service connections and set to limit the delivery pressure for individual service connections as is required by local code.
6. **DEAD ENDS** – Where feasible, dead ends should be minimized by the looping of distribution mains. Dead-end mains should be provided with a fire hydrant if flow and pressure are sufficient, or with an approved flushing hydrant, or a blow-off for flushing purposes. Flushing devices should be sized to provide a velocity of at least 2.5 ft/sec (0.76 m/s) in the water main being flushed. No flushing device shall be connected directly to any sewer.
- Where dead-end mains are necessary in the first stage of construction of a distribution system, the pipe layout should be designed to ensure adequate circulation in the initially installed system and to accommodate future additions and connections.
7. **REPAIRS, REPLACEMENTS, AND EXTENSIONS OF MAINS** – The system shall be maintained so as to prevent its contamination during necessary repairs, replacements, or extensions of mains. When pressure in any part of the distribution system becomes abnormally low, customers in the area shall be notified of necessary protective health precautions.
8. **FROST** – The crowns of all water pipes should be at least 6 inches (15.2 cm) below the maximum recorded depth of frost penetration in the area of installation. The minimum depth of water mains should be at least 3 ft. (0.9 m) from the ground surface to the top of the pipe.

9. PLASTIC PIPE – Plastic pipe intended for transport of potable water shall be evaluated and certified as safe for this purpose by a testing agency acceptable to KDHE. The evaluation should be in accordance with requirements for chemical extraction, taste, and odor that are no less restrictive than those included in NSF International's ANSI/NSF Standards 14 and 61. The seal or mark of the laboratory making the evaluation shall be included on the pipe.
10. PRESSURE AND LEAKAGE TESTS – Pressure and leakage tests shall be conducted on each newly installed water main in accordance with AWWA standards or KDHE's procedures for pressure and leak testing of water mains (Appendix C). The allowable leakage shall not exceed that established by AWWA standards or KDHE procedures (Appendix C).
11. THRUST BLOCKS – All tees, crosses, wyes, bends, plugs, valves, direction changes, and hydrants shall be provided with thrust blocks, tie rods, or joints designed to prevent movement.
12. VALVES – Each system shall be provided with sufficient valves to permit necessary repairs without undue interruption of service over any appreciable area. Blow-off connections to sewers or sewer manholes are not permitted.
13. SANITARY PRECAUTIONS – Sanitary precautions shall be taken in laying new pipe, especially in preventing the introduction of foreign materials into the pipe. Water should be kept out of the trench where new pipe is laid and the open ends of the pipe shall be plugged or capped overnight to eliminate potential sources of contamination.

The selection of materials is critical for distribution piping in locations when it is likely that the pipe will be exposed to significant concentrations of pollutants comprised of low-molecular-weight petroleum products, organic solvents, or their vapors. Pipe materials such as polyethylene, polybutylene, polyvinyl chloride, and elastomers, such as those used in jointing gaskets and packing glands, may be subject to permeation by lower molecular weight organic solvents or petroleum products. If a water main must pass through such a contaminated area, materials impermeable to the particular contamination shall be used for pipe walls, jointing materials, etc., as certified by the manufacturer of the pipe for at least 25 ft. beyond the perimeter of the area of concern.

14. DISINFECTION – All water shall be properly disinfected (KAR 28-15-19) before it reaches the first (nearest) consumer on the distribution system. Water stored for prolonged periods in reservoirs may require re-disinfection upon re-entry to the system. New mains and repaired main sections shall be disinfected according to applicable AWWA standards or KDHE's procedures for the disinfection of water mains (Appendix D) before being placed in or returned to service. When connections are made to an existing system, the exposed pipe interiors should be thoroughly

wetted with a 1% (10,000 mg/L) or higher concentration chlorine solution before closure.

15. DEPOSITS AND CORROSION – Corrective water treatment should be practiced where excessive deposits of chemical precipitates, biological growths, or corrosion occurs in the mains. Disinfection will control biological growths and water stabilization should be used to control chemical precipitation and minimize pipe corrosion (Section L of Chapter V, Stabilization).

Chemicals added to the water for corrosion control shall conform to applicable AWWA standards, shall be certified to NSF International's ANSI/NSF Standard 60: Drinking Water Treatment Chemicals – Health Effects, or equivalent, shall be acceptable to KDHE, and shall protect public health and the environment (KAR 25-05-18(h)). The corrosive effects of finished water on non-ferrous metal pipe used for water service lines should be considered, including possible toxicological effects upon consumers resulting from dissolution of the metals.

Water mains shall be protected from exterior corrosion by use of selected material for backfill or by wrapping or coating the pipe exterior with protective material. A 10-point soil evaluation procedure for predicting conditions corrosive to underground piping is provided in AWWA Standard C105.

16. PLUMBING – Water services and plumbing shall conform to all local plumbing codes.

C. MATERIALS AND INSTALLATION

1. USED PIPE – Water mains that meet the above standards may be reused but only after the pipe has been thoroughly cleaned and restored as much as possible to its original condition.
2. JOINT MATERIALS – Materials used in pipe joints shall meet applicable AWWA standards. Mechanical joints or slip-on joints with rubber gaskets are preferred. Gaskets containing lead shall not be used. Repairs to lead-joint pipe shall be made using alternative materials. Manufacturer approved transition joints shall be used between dissimilar piping materials. Solvent weld joints will not be approved for water mains, but may be used for service connections with pipe sizes less than 2 inches (5.1 cm).
3. AIR RELIEF VALVES, COMBINED AIR/VACUUM RELIEF VALVES, AND BLOW-OFF CHAMBERS – At high points in water mains where air can accumulate, provision shall be made to remove air by means of hydrants or air relief valves. Automatic air relief or combined air/vacuum relief valves shall not be used where flooding of the manhole or chamber may occur.

The open end of the air relief pipe from an automatically operated valve shall be extended to at least 1 ft. (0.3 m) above grade and provided with a screened, downward-facing elbow. The open end of the air relief pipe from a manually operated air relief valve should be extended to the top of the pit. Manual operation of an automatic air relief valve shall be possible.

The open end of the relief pipe from a manual or automatic combined air/vacuum relief valve shall always be extended to at least 1 ft. (0.3 m) above grade and provided with a screened, downward-facing elbow. Termination of the open end of the pipe from a manual or automatic combined air/vacuum relief valve at the top of the pit will not be approved. Manual operation of an automatic combined air/vacuum relief valve shall be possible.

Chambers or pits containing valves, blow-offs, meters, or other such appurtenances to a distribution system, shall not be connected directly to any storm drain or sanitary sewer, nor shall blow-offs, air relief valves, or combined air/vacuum relief valves be connected directly to any sewer. Such chambers or pits shall be drained to the surface of the ground where they are not subject to flooding by surface water, or to absorption pits underground.

Air relief and combined air/vacuum relief valves should be located as close to the pipe as possible with all interconnecting (riser) pipe to be oriented upward to the valve from the water line. Isolation valves should be the same size as the interconnecting piping and should be located between the water line and valves.

4. FIRE HYDRANTS – Because freezing temperatures are a concern for distribution systems in this region, only "dry-barrel" hydrants will be approved for installation and such hydrants shall comply with AWWA Standard C502. Hydrant drains shall not be connected to a sanitary sewer or storm sewer. Specifications for installation of hydrants may be found in the AWWA Manual of Water Supply Practices M17 (AWWA, 1989).

Fire hydrants should be connected only to water mains adequately sized to carry fire flows, and located to permit flushing of all mains and in compliance with local fire code requirements. Generally, fire hydrants should be provided at each street intersection and at intermediate points between intersections. Hydrant spacing may range from 350 to 600 ft. (107 to 183 m) depending on the area being served and the design flow. Additional discussion of criteria for the location of hydrants can be found in the AWWA Manual of Water Supply Practices M31 (AWWA, 1998).

5. INSTALLATION OF MAINS – Installation should follow applicable AWWA standards, AWWA Manuals of Water Supply Practices, and/or the manufacturer's recommended procedures. AWWA standards include C600, *Installation of Ductile-Iron Water Mains and their Appurtenances* and C605, *Underground Installation of Polyvinyl Chloride (PVC) Pressure Pipe and Fittings for Water*. AWWA Manuals

of Water Supply Practices include M23 (AWWA, 2002) for PVC pipe and M11 (AWWA, 2004b) for steel pipe. Widely recognized industry guidelines for the installation of PVC pipe are also provided by the Uni-Bell PVC Pipe Association (Uni-Bell, 2001). Similarly, widely used guidelines for the installation of ductile iron pipe are published by the Ductile Iron Pipe Research Association (DIPRA, 2003).

Continuous, uniform bedding should be provided in the trench for all buried pipe. Backfill material should be tamped in layers around the pipe and to a sufficient height above the pipe to adequately support and protect the pipe. Stone found in the trench shall be removed for a depth of at least 6 inches (15.2 cm) below the bottom of the pipe and replaced with bedding material(s) having appropriate compaction and load bearing properties.

Newly constructed or repaired water distribution mains shall be flushed and disinfected prior to being placed into service (KAR 28-15-18(d)).

D. SYSTEM DESIGN

1. FIELD STUDIES – The hydraulic performance of existing systems is determined most directly and expeditiously by pressure surveys and hydrant-flow tests. Such testing should cover all typical portions of the community, and if need be, they can be extended into every block. The results obtained will establish available pressures and flow, and will reveal existing deficiencies. This information can then be utilized as the basis for hydraulic calculations of extensions, reinforcements, and new grid arrangements. Following the completion of system improvements, additional tests can be conducted to determine the extent to which the desired changes have been accomplished.
2. COMPUTER MODELING – No matter how well or complete the field study is done, hydraulic investigations of extensions and new and existing pipe networks should be confirmed using available computer analysis programs. Guidelines for performing such an analysis can be found in AWWA's Manual of Water Supply Practices M32 (AWWA, 2005b) and *Water Distribution Systems Handbook* (AWWA, 2000).
3. VALVE SPACING – Valves should be placed in numbers and locations that allow control of the system consistent with cost limitations, convenience and minimization of possible sanitary hazards. Valves in smaller mains are typically more numerous than those in larger mains. In transmission lines, valve spacing is determined by operating requirements, and thus it is a matter of individual design. Typical limits on valve spacing in distribution systems are not more than 500 ft. (152 m) in commercial districts, not more than one block or 800 ft. (244 m) in other districts, and where customers are widely scattered or where future development is not expected, such as in a rural setting, not more than one to two miles (1.6 to 3.2 km).

4. VALVE SIZING – Valve sizes are normally the same as the water main in which they are installed except that in mains 30 inches (76 cm) in diameter and larger, line valves are sometimes smaller than the main size.

Fire hydrants should have a bottom valve size of at least 5 inches (12.7 cm), one 4.5 inch (11.4 cm) pumper nozzle, and two 2.5 inch (6.4 cm) nozzles. The hydrant lead shall be a minimum of 6 inches (15.2 cm) in diameter. Auxiliary valves shall be installed in all hydrant leads.

Blow-off valves are usually sized to be 6 inches (15.2 cm) for mains 6 to 16 inches (15.2 to 40.6 cm) in diameter, and 8 inches (20.3 cm) for mains 20 inches (50.8 cm) in diameter and larger.

5. VALVE LOCATION – Valves are usually located on the extensions of the various street property lines involved. Where property lines are not involved, the valves should be placed so that they can be referenced with respect to certain obvious monuments. Valves should be readily accessible in the event of a main failure.

Branch mains connecting to larger primary or secondary feeders that cross under an arterial highway or street should have the valve located close to the larger main and before the crossing.

Blow-off valves and fire hydrant valves should be located as close to the connected main as possible.

Buried valves normally are contained in a conventional valve box assembly. Vaults are not necessarily required.

6. METERING – Each service connection shall be metered. A routine testing program is needed to check the accuracy of all meters in the system. Inoperable or malfunctioning meters should be repaired or replaced. Abnormal water usage should be investigated to insure that service connections are not leaking or broken, especially where geologic conditions may prevent detection of leakage by observation.

Master meters that meter water supplied to distribution systems should be checked periodically for accuracy. They may either over-register or under-register. The percentage of error as determined during an in-place test of the meter is reflective of the meter's accuracy and an indication of when it would be appropriate to replace it with a new meter. Factors such as water quality, flow rate, total quantity measured, chemical deposition and physical abrasion can adversely impact a meter's accuracy. Proper selection and installation of master meters is important.

When planning a master meter installation, attention should be given to providing adequate lengths of straight pipe upstream and downstream of the meter to ensure

maximum uniformity of flow and hence accurate registration. Provisions for testing a master meter in place without interruption of service by use of a test plug and a comparative test meter should be included in the design of the installation. Where a single meter is installed, a bypass circuit should be provided so that meter maintenance can be accomplished without interrupting service.

Meters shall meet applicable AWWA standards. Recommended practices for the selection, installation, testing, and maintenance of water meters are provided in the AWWA Manual of Water Supply Practices M6 (AWWA, 1999b).

7. WATER LOADING STATIONS – Water loading stations present special problems since the fill line may be used for filling both potable water vessels and other tanks or contaminated vessels. To prevent contamination of both the public supply and potable water vessels to be filled, the following requirements shall apply to the design of water loading stations.
 - a. A backflow prevention assembly, device, or method shall be utilized to prevent any backflow to the PWSS. Preventing backflow into a loading station by providing a mandatory air gap between the receiving tank, vessel, or container and the discharge end of the potable water supply pipeline of not less than 2 times the diameter of the water delivery spout opening is preferred. Alternatively a backflow prevention device or a vacuum breaker device that meets KDHE requirements may be installed.
 - b. The piping arrangement shall preclude the transmission of any type of contamination from a hauling vessel to other hauling vessels that subsequently utilize the fill station.
 - c. Hose lengths shall be restricted to prevent contamination through contact with the ground.

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CHAPTER IX
CHEMICAL STORAGE, HANDLING AND APPLICATION

A. BASIC CONSIDERATIONS

1. PLANS AND SPECIFICATIONS – Plans and specifications submitted to KDHE for review and consideration for approval shall include:
 - a. Feed equipment descriptions, maximum and minimum feed ranges and accuracy, and materials of construction when specific materials are required or precluded.
 - b. Location of feeders, piping layout, and points of applications.
 - c. Storage and handling facilities.
 - d. Specifications for chemicals to be used, including information regarding their certification for direct or indirect use in drinking water applications, when chemicals are specified.
 - e. Operating and control procedures including proposed application rates.
 - f. Descriptions of testing equipment and procedures.
2. CHEMICAL APPLICATION – Chemicals should be applied to the water at such points and by such means as to:
 - a. Provide a high degree of safety to the consumers and operators of a PWSS.
 - b. Provide adequate flexibility of operation through various points of application, when appropriate.
 - c. Prevent backflow or back siphonage between multiple points of feed through a common manifold, and prevent overdosing due to siphoning.
 - d. Prevent clogging, deterioration, or malfunctioning of valves, sluice gates, or other equipment, e.g., do not add lime slurry just upstream from a sluice gate.
 - e. Facilitate cleaning, maintenance, and proper mixing of chemicals and water.

- f. Chemical feed points should be located at an adequate distance upstream of where treatment sequences divide and where samples are collected to ensure thorough mixing and distribution of the chemical in the water being treated.

3. FEED EQUIPMENT

a. NUMBER OF FEEDERS

- 1) A separate feeder shall be used for each chemical applied except where the feeder can be used for other chemicals after appropriate cleaning and adjustments.
- 2) Where chemical feed is required for the protection of the PWSS, e.g., for disinfection, coagulation, or other essential processes, standby feeders are required.
- 3) The capacity of the standby unit or the combined capacity of the remaining units in service should be able to replace the largest unit when it is out of service.
- 4) Spare parts should be available for all feeders.

b. DESIGN AND CAPACITY

- 1) Feeders should be able to supply at all times the necessary amounts of chemicals at an accurate rate (+/- 5 percent) throughout the expected feed ranges.
- 2) Chemical feeders should be adjustable so that the chemicals can be added in proportion to flow or the amount of contaminant in the untreated water. Provisions should be made for measuring the quantities of chemicals used.
- 3) Weighing Scales
 - a) Shall be provided for weighing cylinders at all plants utilizing chlorine gas.
 - b) Should be provided for fluoride solution containers.
 - c) Shall accurately measure increments of one percent of the maximum load of the scale.

- 4) Positive displacement type solution feed pumps should generally be used to feed liquid chemicals. However, centrifugal pumps are approved for delivering coagulants. Pumps requiring check valves should not be used to pump slurries. Pumps must be sized to match or exceed maximum head conditions found at the point of injection.
 - 5) Service supply water lines shall be protected from possible contamination by chemical solutions using either of the following:
 - a) Equipping the supply and feed lines with backflow or back siphonage prevention devices.
 - b) Providing an air gap between the supply line and the solution tank.
 - 6) Contact materials and surfaces shall be resistant to the aggressive nature of the chemical solutions being employed.
 - 7) Dry chemical feeders with solution tanks should be designed to provide adequate solution water and agitation of the chemical in the solution pot, and to provide for gravity feed.
 - 8) Chemical bins or dry tanks should be completely enclosed to minimize dust releases to the operating room and to the outdoors. All bins should be equipped with dust collector bags.
 - 9) No direct connection shall exist between any sewer and a drain or overflow from the feeder or solution chamber or tank by providing that all drains terminate at least 6 inches (15.2 cm) or two pipe diameters, whichever is greater, above the overflow rim of a receiving sump, conduit, or waste receptacle.
- c. LOCATION – Chemical feed equipment should:
- 1) Be located reasonably close to the point of application.
 - 2) Be readily accessible for servicing, repair, observation and operation.
 - 3) Be located in a separate room to reduce hazards and dust problems.
 - 4) Be provided with protective curbing or other spill containment so that chemicals from equipment failure, spillage, or accidental drainage will not enter the water in conduits, treatment basins, or storage basins; disperse into high personnel traffic areas; or be discharged out onto bare ground.

d. FEED LINES – Chemical feed lines should be:

- 1) Separate, with each chemical carried in a separate line.
- 2) Accessible, yet adequately protected, i.e., exposed lines and lines encased in concrete floors or walks should be avoided. Lime slurry should be carried in an open flume or other readily cleaned conduit where possible, and the line should be readily accessible to permit inspection.
- 3) Reasonably short in length; of durable, corrosion resistant material; easily accessible throughout the entire length; protected against freezing; and readily cleanable.
- 4) Adequately sloped upward from the source to provide drainage where condensation or reliquefaction of gases may occur, or adequately sloped downward from the source to prevent pumps from being vapor locked by liquid chemicals prone to degassing. In the latter case, siphoning must be prevented.
- 5) Designed to minimize the corrosive potential of chemicals, e.g., through the use of dilution water and diffuser systems.
- 6) Designed to avoid scale formation or solids deposition by the water, chemical, solution, or mixture conveyed.
- 7) Color coded (Table III-1 in Chapter III, General Facilities Considerations).

e. CONTROLS

- 1) Feeders may be manually or automatically controlled, but automatic controls must be capable of manual operation when necessary.
- 2) Automatic chemical dose or residual analyzers are desirable and should be fitted with alarms for critical values, and with recording charts or with digital readouts and computerized data loggers.
- 3) At automatically operated facilities, chemical feeders shall be electrically interconnected with the delivery pumps. Receptacles for automatically operated chemical feeders shall be non-standard.
- 4) Include provisions to track the quantities of chemicals used.

f. SOLUTION TANKS

- 1) Each solution tank shall be constructed or lined with a material that is compatible with the chemical solutions to be stored in it and certified by the tank supplier for each use.
- 2) Means should be provided in a solution tank to maintain a uniform strength of solution consistent with the nature of the chemical solution. Continuous agitation is necessary to maintain slurries in suspension.
- 3) Two solution tanks of adequate volume may be required to assure the continuity of a chemical supply during the servicing of a solution tank.
- 4) Each tank should be provided with a valved drain.
 - a) All drains should terminate at least 6 inches (15.2 cm) or two pipe diameters, whichever is greater, above the overflow rim of a receiving sump, conduit, or waste receptacle.
 - b) In no case should drains discharge directly into sewers, streams, or water treatment flow. Preferably these discharges should drain to a sump from which they can be disposed of safely.
- 5) Solution tank design should include provisions to indicate the liquid level in the tank.
- 6) Chemical solutions should be kept covered. Large tanks with access openings should have such openings curbed and fitted with overhanging covers.
- 7) Subsurface locations for solution tanks or other types of feed tanks will not be approved.
- 8) Overflow pipes, when provided, should be turned downward with their ends screened, have free discharges, and be located where noticeable. Overflow and vent pipes should be kept separate in order to maximize the protection of the tank from overpressure and vacuum scenarios.
- 9) Provide protective curbing to prevent chemicals from equipment failures, spillages, or accidental discharges from entering into the water in conduits, treatment basins, or storage basins.

- 10) Solution tanks shall be properly labeled to designate their contents.

g. DAY TANKS

- 1) Day tanks shall be provided where bulk storage of liquid chemical is provided. KDHE may, on a case-by-case basis, waive the requirement for a day tank provided the bulk storage and feed system designs for a liquid chemical can without exception demonstrate that an overfeed will never occur. Under no circumstances will the day tank requirement be waived for the practice of fluoridation.
- 2) Day tanks shall meet all the requirements for solution tanks.
- 3) Day tanks should hold no more than a 30-hour supply for the average plant flow and average chemical dosages.
- 4) Day tanks shall be scale-mounted, or have a calibrated gauge painted or mounted on the side if liquid level can be observed in a gauge tube or through translucent sidewalls of the tank. In opaque tanks, a gauge rod extending above a reference point at the top of the tank, attached to a float may be used. The ratio of the area of the tank to its height must be such that unit readings are meaningful in relation to the total amount of chemical fed during the day.
- 5) Hand pumps may be provided for transfer from a carboy or drum. A tip rack may be used to permit withdrawal into a bucket from a spigot. Where a motor-driven transfer pump is provided, a liquid level limit switch and an overflow line from the day tank must also be provided.
- 6) A means consistent with the nature of the chemical solution shall be provided to maintain uniform strength of solution in a day tank. Continuous agitation shall be provided to maintain chemical slurries in suspension.
- 7) Tanks shall be properly labeled to designate their contents.

h. SERVICE SUPPLY WATER

- 1) Water used for dissolving dry chemicals, diluting liquid chemicals, or operating chemical feeders shall be:
 - a) Only from a safe, approved source.
 - b) Protected from contamination by appropriate means.

- c) Ample in quantity and adequate in pressure.
 - d) Provided with means for measurement when preparing specific solution concentrations by dilution or for use in determining chemical feed rates.
 - e) Properly treated for hardness when necessary.
 - f) Obtained from a location sufficiently downstream of any chemical feed point to assure adequate mixing.
- 2) Where a booster pump is required, duplicate equipment should be provided, and when necessary, standby power.
 - 3) Backflow prevention should be achieved by appropriate means such as:
 - a) An air gap between the fill pipe and the maximum flow line of the solution or dissolving tank at least two pipe diameters, but not less than 1 inch (2.5 cm).
 - b) An approved reduced pressure zone backflow prevention device, consistent with the degree of hazard, aggressiveness of chemical solution, and available means for maintaining and testing the device.
 - c) Other backflow prevention assemblies or devices more appropriate for a specific application may be approved provided they are consistent with the KDHE's requirements for cross-connection control programs.

4. CHEMICALS

a. QUALITY

- 1) Chemicals shall meet the most recent requirements of applicable AWWA standards and NSF International's ANSI/NSF Standard 60: Drinking Water Treatment Chemicals – Health Effects, or equivalent, be acceptable to KDHE, and shall protect public health and the environment (KAR 28-15-18(h)).
- 2) Assays for chemicals delivered may be required.

- 3) Chemicals having a distinguishing color may be used, providing the coloring material is not toxic in the concentrations used and will not impart taste and odor or color to the treated water supply.

b. SHIPPING CONTAINERS

- 1) A shipping container shall be both compatible with its contents and appropriate in style of construction to facilitate its handling and the transfer and/or application of the chemical in the treatment process.
- 2) Name of chemical, purity, and concentration shall be clearly indicated on the container label.
- 3) Supplier name and address shall be clearly indicated on the container label.
- 4) All relevant certifications shall be clearly indicated on the container label as is required by the certifying entities.

- c. PROTECTIVE MEASURES – Recommended safety requirements and protective measures for handling of all chemicals utilized by a PWSS should be determined and recorded in the PWSS's safety procedures manual. Sources of information about a particular chemical include the Material Safety Data Sheet, product label, chemical manufacturer, associated trade associations such as The Chlorine Institute, and relevant information compiled by regulatory agencies. These safety procedures should be reviewed regularly with all personnel. New employees who may be exposed to a chemical in handling or storage should be thoroughly instructed in the PWSS's safety requirements and protective measures for the chemical.

d. STORAGE

- 1) The space provided shall be sufficient for:
 - a) At least 30 days of chemical supply based on the average flow and dosage conditions; however, space needs should be adjusted to account for delivery time and needs for maximum process conditions.
 - b) Convenient and efficient handling of each chemical stored.
- 2) Storage tanks and pipelines for liquid chemicals shall be specific to the chemicals unless the facilities are completely purged or cleaned before an alternate chemical is used.

- 3) Liquid chemical storage tanks shall have a liquid level indicator, an overflow pipe, a vent (separate from the overflow pipe), and either a receiving basin, capable of holding 110 percent of the stored volume, or a drain capable of receiving accidental spills or overflows. Hazardous materials may require extra precautions.
- 4) Special precautions shall be taken with materials requiring isolated, fireproof storage or explosion-proof electrical outlets, lights, and motors in the chemical handling areas.
- 5) Chemicals should be stored in covered or unopened shipping containers, unless the chemical is transferred into an approved covered storage unit.
- 6) Acid storage tanks shall be vented to the outside atmosphere, but not through vents in common with other storage tanks or day tanks.

e. HANDLING

- 1) The materials of construction of pipes to be used in the transport of chemicals must be corrosion resistant at working temperatures and pressures.
- 2) Chemicals that are incompatible should not be fed, stored, or handled together.
- 3) Provisions should be made for the proper transfer of dry chemicals from shipping containers to storage bins or hoppers to minimize the quantity of dust that may enter the room in which the equipment is installed or be released to the outdoors. Control should be provided by use of:
 - a) Vacuum pneumatic equipment or closed conveyer systems.
 - b) Facilities designed specifically for emptying shipping containers in special enclosures.
 - c) Dust filters and exhaust fan systems that place hoppers or bins under negative pressure.
- 4) Carts, elevators, and other appropriate means should be provided for lifting and moving chemical containers to minimize handling by operators.

- 5) Provisions should be made for disposing of empty bags, drums, or barrels, either by burning or by some other approved procedure that will minimize exposure to dusts.
- 6) Provision should be made for the proper transfer of dry chemicals from storage to the chemical feed device so as to minimize the quantity of dust that may enter the room. Gravity and conveyor systems should be dust tight and adequately ventilated.
- 7) Appropriate vibrators, live bottoms, air sweeps or other devices should be installed on bulk storage bins to prevent bridging and compaction of stored materials.

f. HOUSING

- 1) Structures, rooms, and areas accommodating chemical feed equipment and storage containers should provide dry conditions and convenient access for servicing, repair, observation and operation.
- 2) Floor surfaces should be smooth, impervious, and well-drained with a minimum slope of 2 inches (5.1 cm) per 10 ft. (3.0 m). Where slipping hazards are a concern, particularly at facilities that utilize slippery materials in their treatment sequence such as polymers, a coarse non-slip floor finish or grit-top grating should be considered.
- 3) Open basins, tanks, and conduits should be protected from chemical spills or accidental drainage.
- 4) Pipes and feed lines through interior walls should be sealed with non-shrink grout or some other positive means.
- 5) Vents from feeders, storage facilities, and equipment exhaust shall discharge to appropriate pollution control devices before being safely released to the atmosphere at an elevation that is adequately above grade and at a location that is sufficiently remote from all air intakes.

g. OPERATOR SAFETY

- 1) Open basins, tanks, and conduits should be protected from chemical spills or accidental drainage.
- 2) At least one pair of rubber gloves, a dust respirator of a type approved by NIOSH for toxic dusts, and an apron or other protective clothing should be provided for each operator on any shift who will handle dry

chemicals. A deluge shower and an eyewash device should be installed where strong acids and alkalis are used or stored.

- 3) A water holding tank that will allow water to come to room temperature must be installed in the water line feeding the deluge shower and eyewash device. Other methods of water tempering will be considered on an individual basis.
- 4) Facilities should be provided for washing of an operator's person, apparel and protective equipment.
- 5) Other protective equipment shall be provided as necessary.

h. **HAZARDOUS MATERIAL HANDLING AND SPILLS**

Safety provisions for handling hazardous materials and reporting spills of hazardous materials shall be in accordance with all local, state and federal requirements. Risk management plans are required for systems storing regulated materials such as chlorine and ammonia in excess of the threshold amounts specified in the pertinent sections below. Additional information regarding the requirements for storing hazardous materials may be found in the Clean Air Act (112r), OSHA (Section 654), EPCRA, and OSHA's Process Safety Management (29 CFR 1910.119) and Hazard Communication (29 CFR 1910.1200) rules. Security requirements and/or recommendations, in general and for facilities that store large quantities of hazardous materials, may be found in USEPA's "Chemical Accident Prevention: Site Security" (USEPA, 2000b) as well as on their website.

B. CHLORINE GAS REQUIREMENTS

Gas chlorination equipment, piping, and related appurtenances as well as handling practices shall conform to the specifications and recommendations of The Chlorine Institute (The Chlorine Institute, 1997).

1. **CHLORINATOR SPECIFICATIONS**

- a. For gas withdrawal systems, only solution-feed, vacuum-operated chlorinators shall be utilized in which chlorine gas is maintained under vacuum throughout the apparatus. Such systems typically employ a chlorine gas ejector that creates a partial vacuum into which chlorine gas is drawn from the cylinder and injected into the supply water to form a concentrated chlorine solution. The concentrated chlorine solution is conveyed through a corrosion-resistant conduit for application to the water being treated. Direct-feed chlorinators that deliver liquid or gaseous chlorine under positive pressure directly to the point of application will not be approved.

Other essential features of a solution-feed, vacuum-operated chlorinator include the following:

- 1) A flow regulating system that will automatically shut off chlorine feed and send an alarm (to the SCADA system, if available) upon loss of vacuum due to such causes as vacuum leak, stoppage in the chlorine solution discharge line, plugging of the ejector, or loss of pressure in the water supply line.
 - 2) Chlorine feed rate indicators appropriately sized for the desired feeding range. If there is a large difference in feed rates between routine and emergency dosages, a feed-rate indicator should be provided for each dosage range to ensure accurate control.
 - 3) A means for setting or controlling the rate of chlorine such as a regulating diaphragm assembly. Automatic proportioning feed rate controls shall be provided where the rate of flow or chlorine demand is not reasonably constant. The equipment shall be of such a design that it will operate accurately over the desired feed range.
 - 4) A check valve or other flow interlock device to prevent the backflow of water into the chlorinator.
 - 5) A means to vent gas to the outside or to a scrubber in the event that the chlorine feed regulating system should leak during shutdown.
 - 6) Gauges for measuring water pressure in the water supply line to the ejector and in the chlorine solution line at the outlet of the ejector. Further, a vacuum gauge should be provided in the vacuum line between the ejector and the chlorinator.
- b. Filters and traps ahead of chlorinator vacuum regulating valves and control apparatus are desirable to prevent impurities inherent in chlorine from plugging and damaging chlorine regulators and control mechanisms.
- c. Each chlorine gas ejector must be selected for the point of application with particular attention given to the quantity of chlorine to be added, the maximum ejector water flow, the total discharge back pressure, the required ejector operating pressure for creation of vacuum, and the size of the chlorine solution lines. In order to establish sufficient ejector operating pressure, a booster pump may need to be provided in the water supply line. The water supply to each ejector shall have a separate shut-off valve. A master shut-off valve will not be approved.

- d. The concentrated chlorine solution should be thoroughly mixed with the water being treated. The center of a pipeline is typically the preferred application point. A mixer or diffuser may be needed to adequately disperse the chlorine solution into the flow in a large conduit.
- e. An installed and operable chlorinator sufficient in capacity to replace the largest unit in service shall be provided. An installed and operable duplicate chlorinator shall be provided for smaller systems where only one chlorinator is required. Alternatively, a spare parts inventory sufficient to insure no interruption in the delivery of properly disinfected water may be provided.

2. CHLORINE CYLINDERS AND CONTAINERS

- a. Chlorine cylinders and containers should be fabricated to DOT and The Chlorine Institute's specifications (The Chlorine Institute, 1997).
- b. All cylinders and containers should be equipped with at least one pressure (or safety) relief device with provisions to appropriately direct a non-release, i.e., a small leak, to a ventilation system and a release to a scrubber. Fusible plugs/links do not need to be vented.
- c. Full and empty cylinders of chlorine gas shall be:
 - 1) Isolated from operating areas.
 - 2) Adequately secured by chains (if used in a vertical, upright position), trunnions or cradles (for one ton containers), or other devices.
 - 3) Stored in rooms separate from ammonia storage.
 - 4) Stored in areas not in direct sunlight or exposed to excessive heat.
 - 5) For the safe handling of a one ton container, a lifting bar of the type recommended by The Chlorine Institute must be used in combination with a hoist or crane having a capacity of at least 2 tons (1,814 kg). One ton containers must be stored so that they will not receive direct sunlight or be contacted by rain or snow. Trunnions should be provided for storing one ton containers.
 - 6) Scales must be provided to determine the amount of chlorine applied to the water as indicated by the loss in weight in the chlorine cylinders or containers.

3. CHLORINATOR PIPING

- a. **CROSS-CONNECTION PROTECTION** – The chlorinator's water supply piping shall be designed to prevent contamination of the treated water supply by sources of questionable quality. At all facilities treating surface water, pre-filter and post-filter chlorination systems must be independent to prevent possible siphoning of partially treated water into the clearwell.
- b. **PIPING** – Pipes carrying elemental liquid or dry gaseous chlorine under pressure must be Schedule 80 seamless steel tubing or other materials (never PVC) as recommended by The Chlorine Institute (The Chlorine Institute, 1997). Piping arrangements should be as short and simple as possible, preferably above ground. The number of pipe joints should be held to a minimum. Piping systems should be well supported and adequately sloped to allow drainage. Low spots should be avoided.
- c. **CONNECTING LINES** – Direct-cylinder mounted vacuum regulators or gas chlorinators are recommended where connecting two or more cylinders to a manifold is not necessary. This avoids the utilization of flexible connectors or other connecting pipe between the cylinder and the gas chlorinator and thus eliminates the significant safety hazards that would otherwise exist. Reliquefaction of gaseous chlorine upon a decrease in the temperature of the connecting line relative to the gas cylinder is not uncommon. Reliquefaction of chlorine within the connecting line may result in liquid chlorine reaching the chlorinator or lead to premature failure of the line itself. If a connecting line between the cylinder and the chlorinator must be utilized, reliquefaction may be prevented by installation of an external chlorine pressure reducing valve close to the cylinder or by insulating the line. Pressurized chlorine feed lines shall not carry chlorine gas beyond the chlorinator room.
- d. **COLOR CODING** – All piping carrying chlorine gas or chlorine solution should be color coded as specified in Table III-1 of Chapter III, General Facilities Considerations.
- e. **MATERIALS FOR CHLORINE SOLUTIONS** – Rubber, PVC, polyethylene, or other materials recommended by The Chlorine Institute must be used for chlorine solution piping and fittings. Nylon products are not acceptable for any part of the chlorine solution piping system.
- f. **THERMAL EXPANSION** – Suitable allowance should be made for pipe expansion due to changes in temperature. This is particularly true in the transport of liquid chlorine as it has a high coefficient of thermal expansion. High pressures can develop as the result of an increase in the temperature of the chlorine. This could result in hydrostatic rupture of the chlorine line. The

effects of a possible line rupture must be considered in the design of any piping system.

- g. **AUTOMATIC SWITCH-OVER** – Automatic switchover of chlorine cylinders or containers should be provided, where necessary, to assure continuous disinfection.
- h. **WITHDRAWAL RATES** – The chlorine gas discharge (withdrawal) rate should not exceed 1.5 lbs/hr (0.68 kg/hr) from a single 100-lb chlorine cylinder, 1.8 lbs/hr (0.82 kg/hr) from a single 150-lb chlorine cylinder, or 15 lbs/hr (6.8 kg/hr) from a single one ton chlorine container. The assumptions underlying these permissible discharge rates include an ambient temperature around the cylinder or container of 60 °F (16 °C), natural air circulation, and a gauge pressure against which the cylinder or container is discharging of 21 psi (145 kPa). Higher withdrawal rates from cylinders or containers can be achieved by either manifolding multiple cylinders, or installing an evaporator to evaporate the liquid chlorine withdrawn from chlorine cylinders or containers.

- 4. **TESTING EQUIPMENT** – Chlorine residual test equipment employing a method recognized in the latest edition of *Standard Methods* (APHA *et al.*, 2005) shall be provided, and should be capable of measuring residuals to the nearest 0.1 mg/L. Automatic chlorine residual recorders should be provided where the chlorine demand varies appreciably over a short period of time. All treatment plants having a capacity of at least 0.5 MGD (1,893 m³/day) or serving a population greater than 3,300 persons should be equipped with recording chlorine analyzers monitoring water entering the distribution system. Consideration should be given to utilizing on-line chlorine analyzers to send an alarm to the SCADA system when chlorine residuals in the treated water are inadequate.
- 5. **RESPIRATORY PROTECTION EQUIPMENT** – Respiratory protection equipment meeting the requirements of the National Institute for Occupational Safety and Health (NIOSH) shall be available where chlorine gas is handled, and shall be stored outside every room where chlorine is used or stored. Respiratory protection equipment may consist of either an air purifying respirator (canister gas mask type) designed for chlorine gas or an air supplied respirator such as a self-contained breathing apparatus.

Air supplied respirators are recommended over air purifying respirators for the following reasons. Air purifying respirators do not compensate for the lack of oxygen. A minimum of 19.5 percent oxygen by volume must be present before such respirators can be used. They are also subject to the manufacturer's stated use limitations for the particular contaminant. Most chlorine releases are at low concentrations and canister gas masks would ordinarily offer adequate protection. However, it would not be possible to confirm that a canister gas mask would offer

adequate protection in all situations unless a reliable, continuously operated chlorine monitoring/detection/alarm system was located in the vicinity of the leak.

6. CHLORINE GAS FEED AND STORAGE ROOM SPECIFICATIONS

- a. Chlorine gas feed and storage areas shall be enclosed and separated from other operating areas. Each room shall be:
 - 1) Provided with a shatter resistant, gas tight, inspection window installed in a door or interior wall of the chlorine room to permit the chlorinator(s) to be viewed without entering the room.
 - 2) Constructed in such a manner that all openings between the chlorine room and the remainder of the plant are sealed.
 - 3) Provided with doors equipped with panic hardware, assuring ready means of exit and opening outward only to the building exterior.
 - 4) Provided with sufficient space for a scale and storage of at least one spare cylinder or container for each one connected in service.
 - 5) Posted with appropriate warning signs as required by the emergency preparedness agency or local fire department having jurisdiction over the facility.
- b. Where chlorine gas is used, the room shall be reasonably gas tight and constructed as follows:
 - 1) Each room shall have a ventilating fan with a capacity of one complete air change per minute when the room is occupied.
 - 2) The ventilating fan shall take suction near the floor as far as practical from the door and air inlet, with the point of discharge so located as not to contaminate air inlets to any rooms or structures.
 - 3) Air inlets should be through louvers near the ceiling.
 - 4) Louvers for chlorine room air intake and exhaust shall facilitate airtight closure.
 - 5) Separate switches for the fan and lights shall be located outside of the chlorine room and at the inspection window. Outside switches shall be protected from vandalism. A single light indicating fan operation shall be provided at each entrance where the fan can be controlled from more than one point.

- 6) Vents from feeders and storage shall discharge to the outside atmosphere, above ground.
 - 7) The room location should be on the prevailing downwind side of the building away from entrances, windows, louvers, walkways, etc.
 - 8) Floor drains are strongly discouraged. Where provided, the floor drains shall discharge to the outside of the building and shall not be connected to other internal or external drainage systems.
 - 9) Federal regulations (40 CFR 68) promulgated under the authority of Section 112r of the Clean Air Act require utilities having an inventory of more than 2,500 lbs (1,134 kg) of chlorine to develop and implement a risk management plan (RMP). Such a plan may include a system that in the event of a measurable release of chlorine is automatically engaged into operation to collect and neutralize releases of liquid chlorine and/or a scrubber to capture and neutralize releases of chlorine vapor to prevent its discharge into the environment. The system shall be sized to treat the entire contents of the largest storage container on site. Design recommendations and guidance pertaining to such equipment and its operation are provided by White (1999) and The Chlorine Institute's *Chlorine Scrubbing Systems* (The Chlorine Institute, 1998). Local fire codes, especially those based on a regional or national model fire code, may place additional requirements on the storage of chlorine gas.
- c. Chlorinator rooms should be heated to 60 °F (16 °C) and protected from excessive heat. Cylinders and gas lines should be protected from temperatures above that of the feed equipment.

7. LEAK DETECTION, REPAIR AND RECOVERY

- a. A bottle of concentrated ammonium hydroxide solution (56 percent ammonia by weight) shall be available for chlorine leak detection. A white cloud will form when the solution makes contact with chlorine from a leak.
- b. Continuous chlorine leak detection equipment is recommended. Where a leak detector is provided it shall be equipped with both an audible alarm and a warning light. Chlorine monitoring equipment which continuously samples the air and detects the presence of chlorine is available and should be considered in any storage or operating area where chlorine can be released.
- c. Leak repair kits approved by The Chlorine Institute shall be provided where chlorine cylinders, containers, tank cars and tank trucks are used. These kits can be utilized to contain valve leaks by applying hoods and gaskets. Patches

are provided for sealing off small holes in the side wall of cylinders and containers.

- d. Chlorine recovery vessels are recommended where 150-lb chlorine cylinders are used. Chlorine from the leaking cylinder may be recovered from the vessel once the leaking cylinder has been secured inside the vessel.
- e. Consideration should be given to the use of remotely operated isolation valves where chlorine containers are employed. The isolation valve may be located directly on the chlorine container valve or alternatively in the chlorine line leading from the chlorine container, but as close to the chlorine container as possible.

C. OTHER CHEMICALS

1. HYPOCHLORITES

- a. **STABILITY** – Even under ideal storage conditions hypochlorite solutions gradually decompose. For example, utilizing decomposition rate equations developed by The Chlorine Institute, a 15-percent available chlorine sodium hypochlorite solution is estimated to decompose to 7.5-percent available chlorine in 136 days in storage at 65 °F (18 °C) (The Chlorine Institute, 2000). The rate of hypochlorite decomposition increases with increasing concentration and temperature, is more rapid at pH values below 11, and is catalyzed by light and metal impurities, especially iron, copper, and nickel. To minimize the loss of available chlorine and to minimize the formation of chlorite and chlorate (byproducts of hypochlorite decomposition), the following practices are recommended:
 - 1) Manage the hypochlorite inventory to avoid unnecessarily long storage times (with 28 days being a reasonable target) consistent with the need to ensure continuous disinfection;
 - 2) Dilute hypochlorite solutions upon receipt (to 5 to 10 percent available chlorine), preferably with softened water to minimize softening reactions that may require periodic removal of precipitates from the storage tank and to reduce the concentrations of metals that catalyze the decomposition of hypochlorite;
 - 3) Store hypochlorite solutions in the dark and at a temperature below 70 °F (21 °C) and at pH 11.0 to 11.2 (higher pH values do not improve stability, but may increase the chemical dosages needed for stabilization of the finished water);

- 4) Specify hypochlorite solutions free of sediment and suspended solids and having less than 0.5 mg/L of iron, copper and nickel (White, 1999); and
 - 5) Avoid bringing hypochlorite solutions into contact with incompatible materials.
- b. CONTAINERS – Sodium hypochlorite solution is often shipped in 5 and 55 gallon (19 and 210 L) drums and stored in the drums prior to use. The drums must meet DOT specifications and are generally manufactured of polyethylene. Sodium hypochlorite solutions of 7 percent by weight or greater must be stored in vented containers. If the venting rate is exceeded by the decomposition rate, swelling of the container may be apparent. Care must be taken when opening containers containing sodium hypochlorite solutions to detect and properly release excess pressure.
- c. MATERIALS – As a general rule, metal should not be allowed to come in contact with sodium hypochlorite solution. Mild steel, stainless steel, and virtually all common metals will corrode rapidly on contact with sodium hypochlorite solutions and, in turn, the solutions will decompose much more rapidly.

Plastic pipe is commonly employed to carry hypochlorite solutions, however great care must be exercised in the selection of materials for this service. It is at a minimum important to evaluate chemical compatibility, structural limitations with respect to operating and surge pressures, and joint integrity. Where glued pipe is employed, the solvent cement utilized during construction of the pipe system must be compatible with both the pipe material and the hypochlorite solution.

Schedule 80 PVC is the most commonly used pipe material; but PVC pipe can develop cracks after prolonged exposure to hypochlorite solutions (White, 1999). PVDF is the preferred material for both pipe and fittings (White, 1999). CPVC, though more expensive than PVC, has been found to provide better resistance to hypochlorite, especially when it is exposed to UV light or temperatures above 73 °F (23 °C) (White, 1999)(Joslyn and Gaddis, 2001). Steel pipes lined with polypropylene, PVDF, or PVDC can also be used, especially for underground piping (White, 1999); and steel valves lined with PVC, PVDC, PVDF or hard rubber, are acceptable (AWWA and ASCE, 2005).

Storage tanks should be constructed of FRP, polyethylene, or steel lined with rubber or polyethylene (White 1999); but the resin used in an FRP tank (and in either wall of a double-walled tank) must be compatible with hypochlorite (Joslyn and Gaddis, 2001). In general, it is important that the processes

utilized to manufacture FRP tanks employ appropriate resins and catalyst setting systems, and that the tanks be post cured. Diffusers should be made of PVC, PVDF, or rubber-lined and covered steel (White, 1999).

- d. **DANGEROUS REACTIONS** – Hypochlorites should never be mixed with acids, ammonia solutions, or solids containing ammonium salts. Hazardous gases may be formed; and excessive heat or pressure may be generated. Further, hypochlorites may react violently with many organic compounds including greases, oils, fuels, etc.
- e. **PERSONAL PROTECTION** – When handling calcium or sodium hypochlorite, it must never be allowed to contact the eyes. Hypochlorites can cause serious burns on the skin and damage to the lungs. When handling these materials, the operator should wear a protective apron, rubber gloves, eye protection, and respiratory equipment.
- f. **GAS RELEASE** – Hypochlorite releases small amounts of gas (oxygen) as it decomposes. Gas buildup has reportedly led to failure of PVC ball valves (AWWA and ASCE, 2005) and can cause vapor lock in feeding systems. Vapor lock, and the underdosing associated with it, can be avoided or minimized by: using gravity feed systems; using flow meters or rotameters to verify feed rates; installing degassing valves; and sloping tubing or piping downward toward the feed pumps to allow gas bubbles to escape back into the storage tank (Joslyn and Gaddis, 2001).
- g. **FEEDERS** – Positive displacement pumps with hypochlorite compatible materials for wetted surfaces are recommended. Small diameter suction lines should be used with foot valves in smaller installations. In larger installations, flooded suction should be used with piping arranged to promote escape of gas bubbles. Calibration tubes or mass flow monitors which allow for direct physical checking of actual feed rates should be employed.

2. ACIDS AND CAUSTICS

- a. Acids and caustics shall be kept in closed, corrosion-resistant, shipping containers or storage units.
- b. Acids and caustics shall not be handled in open vessels, but should be pumped in undiluted form from original containers through suitable hoses, to the point of treatment or to a covered day tank.

3. SODIUM CHLORITE FOR CHLORINE DIOXIDE GENERATION – Chlorine dioxide is generated on-site because of its explosive properties when stored. It is continuously generated, typically by oxidizing sodium chlorite with aqueous or gaseous chlorine or electrochemically. Several different methods are employed

commercially. Proposals for the storage and use of sodium chlorite must be approved by KDHE prior to the preparation of final plans and specifications. Provisions shall be made for proper storage and handling of sodium chlorite to eliminate any danger of explosion.

a. STORAGE

- 1) Sodium chlorite shall be stored by itself in a separate room and preferably stored in an outside building detached from the water treatment facility. It must be stored away from organic materials, many of which will catch fire and burn violently should they come in contact with chlorite, and shielded from exposure to sunlight, UV light, and heat, which will reduce product strength and increase byproduct formation. Shielding is recommended by the USEPA's *Guidance Manual for Alternative Disinfectants and Oxidants* (USEPA, 1999b).
- 2) The storage structure shall be constructed of noncombustible materials.
- 3) If the storage structure must be located in an area where a fire may occur, water sprinklers must be available to keep the sodium chlorite area cool enough to prevent decomposition from heat and the resultant explosive conditions.
- 4) High-density polyethylene is recommended over fiber-reinforced polyester or plastic for storage and day tanks. If fiberglass is used, the proper resins must be selected, since some polymers will degrade in contact with chlorite (Gates, 1998).
- 5) Secondary containment should be provided in storage and handling areas, including sumps to facilitate product recovery; and a water supply should be available for cleanup. Additional information can be found in USEPA's *Guidance Manual for Alternative Disinfectants and Oxidants* (USEPA, 1999b).

b. HANDLING

- 1) Care should be taken to prevent spillage.
- 2) An emergency plan of operation should be available for the clean up of any spillage. Sprinklers shall be provided in housed handling facilities. Adequate ventilation and air monitoring devices should be provided, and gas masks and first aid kits should be available immediately outside the storage area. Additional information can be

found in USEPA's *Guidance Manual for Alternative Disinfectants and Oxidants* (USEPA, 1999b).

- 3) Storage drums must be thoroughly flushed prior to recycling or disposal.

c. **FEEDERS**

- 1) Positive displacement feeders shall be provided for sodium chlorite, sodium hypochlorite, or acid feed, except for systems designed to operate under vacuum. Whether positive displacement or vacuum feeders are used, appropriate safeguards shall be included to insure steady chemical feed rates, to prevent air binding, to prevent chemicals from being siphoned out of, or drawn back into, storage containers or from mixing with one another outside the reaction zone or in unsafe proportions, and to provide adequate safety.
- 2) Tubing for conveying sodium chlorite or chlorine dioxide solutions shall be Schedule 80 CPVC, PTFE, polyethylene, or other materials recommended by the manufacturer. Lines carrying chlorite solutions or chlorine dioxide should never be plumbed directly over foot traffic.
- 3) Chemical feeders may be installed in chlorine rooms if sufficient space is provided or facilities meeting the requirements of chlorine gas shall be provided.
- 4) Feed lines shall be installed in a manner to prevent formation of gas pockets, and shall terminate at a point of positive pressure.
- 5) Check valves shall be provided to prevent the backflow of chlorine into the sodium chlorite line.

4. **AMMONIA**

- a. Ammonia may be fed directly under vacuum or in the form of an ammonium solution prepared from anhydrous ammonia, concentrated aqua ammonia, or ammonium sulfate.
- b. When using anhydrous ammonia, only solution-feed, vacuum-operated gas withdrawal and delivery systems shall be utilized in which anhydrous ammonia gas is maintained under vacuum throughout the apparatus. Liquified anhydrous ammonia causes severe burns on skin contact and is highly toxic when volatilized and inhaled so special precautions must be taken when using this chemical to adequately protect the health and safety of both plant personnel and the public. The equipment and facilities required to

feed anhydrous ammonia are similar to those used to feed chlorine gas (Section B), except that the emergency air exhaust system shall have an elevated intake and special vacuum breakers and regulators must be used to avoid the potentially violent results of backflow of water into a cylinder or storage tank. Direct-feed of liquified or gaseous anhydrous ammonia under positive pressure directly to the point of application will not be approved.

- c. Typical piping materials for solution feed systems are stainless steel, PVC, and black iron; but PVC is used only in the lower-pressure portions of the system and for conveying aqua ammonia, which is highly corrosive (USEPA, 1999b). KDHE recommends the use of black steel pipe for this service since PVC and CPVC have been known to become extremely brittle and break, e.g., shatter like glass, very easily in this service. Copper, bronze, and brass fittings may not be used because ammonia attacks copper as well as copper-based and copper-bearing alloys. Zinc, cadmium, and all of their alloys are also readily attacked by ammonia solutions (Terra Industries, Inc., 2002).
- d. Systems utilizing anhydrous ammonia or aqua ammonia must be designed to prevent the release of hazardous or irritating amounts of ammonia gas. Systems storing more than 10,000 lbs (4,536 kg) of anhydrous ammonia or 20,000 lbs (9,072 kg) of aqua ammonia (20% by weight or greater) are required under Section 112r of the Clean Air Act (40 CFR 68) to prepare risk management plans. The ventilation design requirements for rooms utilized to store anhydrous and aqua ammonia shall follow the requirements for chlorine rooms. Scrubbers may be required to protect the health and safety of employees and the public.
- e. Chlorine gas and anhydrous ammonia, aqua ammonia or ammonium sulfate solutions may not be stored in the same room, and ammonia gas application points must be located at least 5 ft. (1.5 m) away from chlorine solution lines.
- f. Tanks used for outdoor storage of anhydrous ammonia should be protected from extreme temperatures ($< 28^{\circ}\text{F}$ (-2.2°C) and $> 125^{\circ}\text{F}$ (52°C)). Tanks should be painted white, and supplemental heat may be needed during the winter to prevent impairment of ammonia vaporization.
- g. Both atmospheric and pressurized tanks have been utilized to store aqua ammonia, however, KDHE recommends pressurized tanks over atmospheric tanks for bulk storage as atmospheric storage tanks can represent a direct hazard to operating personnel and the surrounding community. Aqua ammonia solutions stronger than 19% by weight should be stored in closed, pressurized tanks, while aqua ammonia solutions with concentrations of up to 19% by weight can be stored in atmospheric tanks fabricated to API 650 Code (Terra Industries, Inc., 2002). Regardless of choice, KDHE

recommends that aqua ammonia storage, transfer and feed systems be designed by qualified personnel having previous experience with the product.

Pressurized bulk storage tanks and transfer facilities shall be sited outdoors and away from enclosed areas. Common materials of construction are carbon steel and stainless steel. Passivation is recommended where carbon steel is selected. Pressurized bulk storage tank design generally consists of low pressure bullet-shaped tanks designed to ASME Section 8, Division 1 Code for working pressures of 30 psig or greater (Terra Industries, Inc., 2002). Bulk storage tanks should be fitted with both a safety relief device and a vacuum breaker to prevent rupture and collapse, respectively, and be grounded. Unloading facilities shall include an ammonia vapor return line to the delivery tanker. Transfer of product may be accomplished by tanker or customer off-loading pumps. Vapor lines and liquid lines should be 1 to 1.25 inches (2.5 to 3.2 cm) and 2 inches (5.1 cm) in diameter, respectively (Tanner Industries, Inc., 1998). A connector incompatible with other chemical deliveries or other lockout provisions shall be made to prevent accidental addition of other chemicals to the storage tank. If the aqua ammonia feed system utilizes a carrier stream to convey aqua ammonia to the treated water stream, the carrier water must be softened water.

Atmospheric bulk storage tanks shall be corrosion resistant, vented through an inert liquid trap to a high point outdoors, adequately contained, and their storage areas well ventilated. Outside delivery connections, an ammonia vapor return line to the delivery tanker, tanker or customer product transfer pump(s), and a connector incompatible with other chemical deliveries or other lockout provisions to prevent accidental addition of other chemicals to the storage tank shall be included in the off-loading design. Aqua ammonia storage tanks shall be fitted with cooling/refrigeration units and/or provisions to dilute the contents with water (with adequate mixing and without opening the tank), such that temperature increases do not cause the vapor pressure of ammonia over the aqua ammonia to exceed atmospheric pressure. If the aqua ammonia feed system utilizes a carrier stream to convey aqua ammonia to the treated water stream, the carrier stream must be softened water.

- h. Aqua ammonia feed pumps and indoor storage facilities shall be enclosed and separated from other areas. The room shall be equipped similarly to that described in Subsection B.6, except that the exhaust fan shall withdraw air from high points in the room and air shall be allowed to enter at a low point. Aqua ammonia feed pumps, regulators, and lines shall be fitted with pressure relief vents discharging to the outside of the building and away from any air intake and with water purge lines leading back to the headspace of the bulk storage tank.

- i. The water used to prepare, dilute or carry an ammonium solution must normally be soft or softened to avoid precipitation of calcium carbonate (or calcium sulfate, if ammonium sulfate is used) and the subsequent clogging of the injector. The ammonia injector should consist of a perforated tube fitted with a closely fitting flexible rubber tubing seal punctured with a number of small slits to delay fouling by lime deposits. Provisions should be made for periodic removal of scale deposits from injectors and carrier piping.
 - j. Pressurized feed lines for anhydrous ammonia and full strength solutions of aqua ammonia shall be restricted to the ammonia storage/feed room. Chemical feed lines carrying a dilute aqua ammonium solution, including those prepared by dissolving anhydrous ammonia in water, shall be appropriately located to ensure optimal and safe delivery of the solution to the point(s) of application.
 - k. Leak detection systems shall be utilized in all indoor areas where anhydrous ammonia is stored or through which anhydrous ammonia is piped.
 - l. A solution of ammonium sulfate is prepared by adding ammonium sulfate to water with agitation. The tank and dosing equipment contact surfaces should be made of corrosion resistant non-metallic materials. Provision should be made for removal of the agitator after dissolving the solid. The tank should be fitted with a lid and vented outdoors.
 - m. Ammonium solutions should be injected below the surface of the water being treated, preferably in the center of the treated water flow, at a location where the water is flowing at a high velocity or has sufficient turbulence to thoroughly mix the ammonium solution with the water being treated. To avoid the release or irritating or harmful vapors, especially when using solutions prepared from anhydrous ammonia or aqua ammonia, concentrated streams of feed solution must not be allowed to rise to the surface of the water being treated.
5. LIME SLURRY – Provisions shall be made to minimize scaling of the pumps, feed lines, troughs and other equipment used for preparing and conveying lime slurries and to facilitate scale removal. Recommendations regarding lime feeding, including scale control and removal, are available from the National Lime Association (1995).
 6. POWDERED ACTIVATED CARBON – PAC shall be handled as a potentially combustible material. It should be stored in a building or compartment as nearly fireproof as possible. Overhead sprinklers are recommended as a precautionary measure. Other chemicals should not be stored in the same place. PAC is not normally explosive, however, it is combustible and will burn when ignited. PAC may not be stored where it can come in contact with gasoline, mineral or vegetable oils; and PAC should never be mixed with or stored near disinfecting or oxidizing

agents. Since activated carbon is an electrical conductor, PAC dust should not be allowed to accumulate near or on open electrical circuits. PAC can be stored as a slurry up to one year without affecting its adsorptive capacity, provided that it is adequately protected from contaminants.

PAC, in dry or slurry form, adsorbs oxygen from the air. Therefore, enclosed spaces where PAC is stored must be adequately ventilated and equipped with oxygen monitors, alarms, and other appropriate safety features.

7. POLYPHOSPHATES – Stock phosphate and polyphosphate solutions should be covered and disinfected by carrying a free chlorine residual of approximately 10 mg/L. Phosphate solutions having a pH of 2.0 or less may be exempted from this requirement by KDHE.
8. POLYMERS – Polymer tanks may require protective paint or plastic liners. Dilution of stock polymers prior to feeding is common. Materials of construction and arrangement of the delivery system should be according to the manufacturer's recommendation. Facilities that utilize polymers should consider a coarse non-slip floor finish or grit-top grating for polymer area floors to minimize slipping hazards.
9. ACTIVATED ALUMINA – Activated alumina should be stored away from gasoline, minerals or vegetable oils, and calcium hypochlorite (AWWA and ASCE, 2005).

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American National Standards Institute (ANSI), 1819 L Street, NW, 6th floor, Washington, DC 20036 (202-293-8020).

American Society of Civil Engineers (ASCE), 1801 Alexander Bell Drive, Reston, Virginia 20191 (800-548-2723).

American Society of Mechanical Engineers (ASME), Three Park Ave, New York, NY 10016 (800-843-2763).

American Society of Testing and Materials (ASTM), 100 Barr Harbor Drive, West Conshohocken, PA 19428 (610-832-9585).

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Centers for Disease Control and Prevention, 1600 Clifton Road, Atlanta, GA, 30333 (404-639-3311).

Ductile Iron Pipe Research Association (DIPRA), 245 Riverchase Parkway East, Suite O, Birmingham, Alabama 35244 (205-402-8700).

Foundation for Cross-Connection Control and Hydraulic Research (FCCCCHR), School of Engineering MC-2531, Kaprielian Hall 200, Los Angeles, CA 90089 (866-545-6340).

Health Education Services, P.O. Box 7126, Albany, NY 12224 (518-439-7286).

ISO, 545 Washington Boulevard, Jersey City, NJ 07310 (800-888-4476).

Kansas Department of Agriculture, Division of Water Resources (DWR), 109 S.W. 9th Street Topeka, KS66612 (785-296-3556).

Kansas Department of Health and Environment (KDHE), Bureau of Water, Public Water Supply Section, 1000 SW Jackson St., Suite 420, Topeka, KS 66612 (785-296-5514).

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Kansas Geological Survey (KGS), Moore Hall, 1930 Constant Ave., West Campus, University of Kansas, Lawrence, KS 66047 (785-864-3965).

Kansas Water Office (KWO), 901 S. Kansas Ave., Topeka, KS 66612 (785-296-3185).

Kansas Water Resources Research Institute, 44 Waters Hall, Kansas State University, Manhattan, Kansas 66506 (785-532-7419).

National Institute for Occupational Safety and Health (NIOSH), 1600 Clifton Road, Atlanta, GA 30333 (404-639-3311).

National Lime Association, 200 North Glebe Road, Suite 800, Arlington, Virginia 22203 (703-243-5463).

NSF International (NSF), PO Box 130140, 789 N. Dixboro Rd, Ann Arbor, MI 48113 (734-769-8010).

Occupational Safety and Health Administration (OSHA), 2000 Constitutional Avenue NW, Washington DC, 20210 (800-321-7642).

Safe Drinking Water Hotline (USEPA): 1-800-426-4791.

State Conservation Commission, Mills Building, 3rd floor, 109 SW 9th St., Suite 500, Topeka, KS 66612 (785 296-3600).

The Chlorine Institute, 1300 Wilson Boulevard, Arlington, VA 22209 (703-741-5760).

Uni-Bell PVC Pipe Association, 2655 Villa Creek Drive, Suite 155, Dallas, TX 75234 (972-243-3902).

University of Southern California, Foundation for Cross-Connection Control and Hydraulic Research, Kaprielian Hall 200, Los Angeles, CA 90089-2531, (800-545-6340).

U.S. Army Corps of Engineers, Headquarters, Executive Office, 441 G. Street, NW, Washington, DC 20314 (202-761-1024).

U.S. Department of Health and Human Services, 200 Independence Avenue, S.W., Washington, D.C. 20201 (202-619-0257).

United States Environmental Protection Agency (USEPA), Ariel Rios Building, 1200 Pennsylvania Avenue, N.W., Washington, DC 20460 (202-272-0167).

APPENDIX A

SELECTED KANSAS STATUTES AND ADMINISTRATIVE REGULATIONS PERTAINING TO PUBLIC WATER SUPPLY

The selected Kansas Administrative Regulations and Kansas Statutes Annotated formerly listed in this appendix are now available in their updated form on KDHE's home page.

Kansas Administrative Regulations:

http://www.kdheks.gov/pws/regs/drinking_water_regs.pdf

Corresponding links to USEPA's Code of Federal Regulations for the National Primary Drinking Water Regulations (40 CFR 141) are also at the above website.

Kansas Statutes Annotated:

http://www.kdheks.gov/pws/download/KS_Statutes_Pertaining_to_Public_Water_Supply.pdf

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APPENDIX B

WATER QUALITY TESTING FOR NEW PUBLIC WATER SUPPLY SOURCES

Analytical Requirements for New Sources

Background

This discussion defines the Bureau of Water's policy regarding water quality test results that must be submitted along with public water supply permit applications for new drinking water source waters. The intent of this policy is to insure that PWSSs comply with primary drinking water standards and monitoring requirements in the course of supplying the public with safe drinking water. This discussion specifically applies to community water supply systems and non-transient non-community water supply systems as defined in KAR 28-15a-2. Analytical requirements for new groundwater sources for transient non-community systems are initially limited to radon, IOCs, and VOCs. KDHE may request collection of additional samples from new sources for analysis for other parameters as is deemed necessary to protect public health. Additional sampling may also be required by KDHE for community and non-transient community water supply system as is deemed necessary in order to protect public health.

Regulations

Maximum contaminant levels, monitoring requirements based on maximum contaminant levels, and monitoring requirements for 15 inorganic contaminants not regulated by a maximum contaminant level (for which monitoring is still required) can be found in KAR 28-15, KAR 28-15a 61-66, KAR 28-15a 23-25, and KAR 28-15a-23, respectively. KAR 28-15-16 sets forth permit requirements for PWSSs. The results of the analyses performed by the KDHE laboratory, or by a laboratory certified by KDHE according to KSA 65-171(l), regarding the physical, bacteriological, chemical and radiological constituents of any untreated source waters must be submitted along with the permit application as part of ensuring that the proposed treatment facilities will be able to reliably produce a potable water meeting the requirements of the primary drinking water regulations established in KAR 28-15a. KSA 65-163 allows the Secretary of Health and Environment to require "... such other data and information as may be required ..." in addition to the specific state permit requirements as part of an application for a public water supply permit.

For a new source of supply, it is important that proper sampling techniques and testing procedures be employed to insure that its subsequent use will not result in an exceedance of a maximum contaminant level, trigger increased monitoring requirements or adversely impact public health.

Required Analyses

A summary of the analytical requirements for new sources can be found in Attachment A. In general, samples are collected from the test well (or new surface source) according to the instructions accompanying the sample containers provided by the laboratory and then submitted

Appendix B: Water Quality Testing for New Public Water Supply Sources

to that laboratory for analyses. Any laboratory certified by KDHE according to the requirements of KSA 65-171(l) may perform the required analyses. Alternatively, the required analyses may be performed by the KDHE laboratory. The results of the analyses must be included with the plans, specifications and permit application for the source water submitted to the KDHE for its review. Except as noted below, the Bureau of Water will not approve the construction of a public water supply well or authorize the use of a new surface source until the results of the source water analyses have been provided for its review. For assistance with analytical requirements, sample bottle requests, scheduling, certified laboratories, and costs contact the KDHE's Bureau of Water at (785) 296-5514.

For new groundwater sources, an initial partial inorganic chemical analysis may be completed on test wells to determine the preferred site for development of the new well. Relevant parameters for this initial screening include calcium, magnesium, sodium, total alkalinity, chloride, sulfate, iron, manganese, nitrate, and total hardness. The analyses for the initial screening may be conducted in the field utilizing portable laboratory kits equipped with a spectrophotometer, available from several laboratory equipment supply companies. If a test well encounters separate aquifers with potentially differing water quality, then each aquifer should be sampled for at least the partial inorganic chemical analysis. If a separate aquifer is determined to be of poor quality, such as a shallow alluvial aquifer with elevated sulfate levels, the water supply well must be designed and constructed so as to adequately seal off that particular aquifer to prevent contamination of the lower aquifers and the well in general.

Once the site for the new well has been identified, samples must be obtained from a site-specific test well and analyzed for all required parameters to insure compliance with the drinking water standards. The test well should be located as close as possible to the site of the proposed well (preferably within 50 ft.) and the water samples collected from the same aquifer that will be screened and isolated in the completed well. If after completing a suitable test drilling program in the area, the water system is unable to locate a source of supply which meets the drinking water standards, a conference may be held with KDHE, the PWSS, and the engineer and/or well driller for the purpose of discussing the options that the water system has regarding the location of a new source, blending, treatment, or connection to adjacent supplies.

Offset Wells

If the PWSS proposes to construct an additional or replacement well in the same aquifer as an existing public water supply well and the proposed well will be located within 300 feet of the existing well, then the results of the chemical analyses of a recent sample from the existing well or the relevant point of entry to the distribution system may be submitted to KDHE for approval as satisfying new source water quality testing requirements provided the results are current and proper analytical methods were employed. It is important to note that the overall water quality of the additional/replacement well could significantly vary from that of the existing well depending on many factors including differences in well construction such as depth of screen or the presence of zones of dissimilar quality within the aquifer. Where there are potential water quality concerns such as elevated nitrate, iron, and manganese, or potential significant variation in the formation,

KDHE recommends additional investigative activities such as the drilling of a test well and sampling for at least a partial mineral analysis and any other parameters of concern.

Other Considerations

Groundwater quality may differ significantly over short distances. Even if water samples are obtained from a test well in compliance with these procedures and current standards, it is still possible that the water from the completed well may exceed drinking water standards for certain constituents that would require blending, treatment, or other methods to achieve compliance.

Recommended Sampling Procedures

Background

All new sources of public water supplies must be tested for chemical quality in accordance with Kansas Administrative Regulations and this discussion. It is imperative that the samples obtained for analyses are representative of the source. This section provides general information to achieve this purpose. It is not intended to be a comprehensive treatment of all potential sampling issues.

Precautions must be taken to insure representative samples of groundwater are collected from test wells. The degree and type of effort and care that goes into a sampling event is dependent on the chemical species of interest and the concentration levels of concern. The objective of this sampling effort is to obtain representative samples of the water in the test well to determine if the water will meet primary drinking water standards. These standards include limits for several volatile organic compounds (VOCs), synthetic organic compounds (SOCs), inorganic chemicals (IOCs), and radionuclides. Today's analytical methods and analytical instruments can detect the presence of these types of parameters to the part per billion. Improper sampling techniques or seemingly insignificant contamination of samples can adversely affect test results and potentially lead to a mischaracterization of a source as exceeding one or more of the primary drinking water standards.

Test Well Construction Considerations

The following well drilling recommendations are provided as part of minimizing the potential of contaminating water samples:

- A. The drilling of test wells does not require prior approval of KDHE. However, test wells must be drilled, completed, properly abandoned, and plugged in conformance with KAR 28-30-1 through 28-30-10. Test well construction must include provisions for a temporary, watertight, lockable cap until such time as the test well has been either completed into a source well or abandoned and plugged.
- B. The drilling rig and all associated items to be introduced into the bore hole must be thoroughly washed with hot potable water or steamed prior to the drill rig entering the drilling site. In addition, the drilling rig's water pump and plumbing system must be thoroughly flushed.

Appendix B: Water Quality Testing for New Public Water Supply Sources

- C. All casing pipe including screened sections must be washed with a low-suds, non-phosphate detergent such as Alconox® and thoroughly rinsed prior to its introduction in the bore hole.
- D. Lubricating oils or solvents should not be used on the drill rod threads.
- E. All water used in the drilling and construction process shall be obtained from a potable water supply source. Sodium bentonite is acceptable for a drilling fluid mud. The use of some organic drilling fluids, such as polymeric additives, may enhance biological activity in the aquifer and should be avoided.

If the formation is not stable enough to support the bore hole, a temporary casing should be installed. A common approach to stabilization is to place material such as gravel pack into the bore hole annulus with a tremie pipe until the level of the material is sufficiently above the screen. Less porous material such as sand followed by a drilling mud may then be placed into the bore hole annulus with a tremie pipe to both seal the well and facilitate the removal of the casing at a later date.

- F. The use of PVC solvent-based cements should be avoided where a temporary casing is installed. Compounds such as tetrahydrofuran, methyl-ethyl-ketone, and toluene have been known to leach into groundwater samples at the milligram per liter or ppm level from PVC well casings whose pipe joints were glued with PVC solvent cements.

Sampling Considerations

A. Purging the Well

After completion, the test well must be purged to remove contaminants left over from the drilling of the well and to ensure that the stagnant regions in the bore hole, e.g. water within the well casing, are thoroughly flushed with water from the aquifer. The volume of water that should be purged in order to obtain samples that are both representative of the aquifer and turbidity free can vary from well to well, however, most wells are considered adequately purged after having been pumped for three to ten well-bore volumes (Driscoll, 1986). The minimum volume of water to be purged as a function of casing diameter and depth may be estimated from the following equation:

$$V = N * 0.0408 * H * D^2$$

where,

- V = volume to be purged, gal
- N = minimum number of purge volumes, dimensionless
- D = inside diameter of the casing, in
- H = height of the water column in the casing, ft

An alternate approach to estimating the minimum purge volume would be to measure water quality parameters such as specific conductance, temperature, pH and turbidity for each well bore volume purged. The well would be considered to have been adequately purged after the trends of these parameters have stabilized for at least three consecutive purge volumes.

The nature of the aquifer, and the sampling equipment and methodology employed, must be taken into consideration to ensure that the well bore is adequately flushed so that the samples are representative of the aquifer. As an example, the number of purge volumes required to flush a well constructed in an aquifer having a high transmissivity may be much higher than estimated above if the well screen is in the lower portion of the casing. In this arrangement, the pump most likely will draw primarily from the aquifer with the region above the pump and screen remaining stagnant. Completely pumping the well bore dry would most likely be impractical; however, it may be practical to monitor the level in the well during the purging process along with the water quality parameters previously noted. Purging could be considered to be complete when the water level and the water quality parameter trends have stabilized (Scaif *et al.*, 1981).

B. Sampling Devices

There are a variety of different sampling devices that can be utilized for collecting groundwater samples. The sampling equipment used must not alter or contaminate the sample. Since samples will be analyzed for trace organic chemicals, special care must be taken as conventional oil-lubricated pumps, plastic tubing and fittings and rubber tubing can be significant sources of contamination. The following devices are recommended for the collection of samples:

1. Positive pressure pumps, such as a non-gas contact bladder pump where water is forced to the surface through positive pressure when operated below the well's water level, will cause the least amount of alteration in sample integrity as compared to other sample retrieval methods. A positive pressure pump may be operated electrically, mechanically, or by air/nitrogen pressure. Any surface on the pump system, including all tubing or piping, that comes into contact with the sample should be made of acceptable materials as defined below. A side tap may be installed on the pump discharge pipe to permit adjustment of the sample stream to a low flow. The tap, however, must not have an aerator.

Negative pressure pumps are not recommended for collection of groundwater samples for organic analyses because removing the groundwater under suction conditions may cause the groundwater being pumped to degas resulting in the loss of volatile compounds. This is also true for peristaltic pumps. A suction lift pump, however, may be utilized for purging the bore hole prior to collection of the sample. Similarly, air lift pumps that apply air pressure to the water well to force a sample out of the discharge tube are not recommended for collection of VOC samples. Such pumps may modify the pH of the water, alter the oxidation

state of certain constituents of interest by introducing oxygen into the sample, and potentially strip out volatile compounds.

2. One of the oldest and simplest methods of sampling a water well is the use of a bailer. A bailer may be in the form of a weighted bottle or capped length of pipe on a rope or some modification thereof is lowered and raised by hand. Bailers constructed entirely of PTFE have been manufactured specially for collecting groundwater samples for analyses. Bailers used for sampling VOCs should have a sample cock or draft valve in or near the bottom of the sampler to allow withdrawal of a sample from the well below the exposed surface of the water. Suspension lines for bailers should be kept off the ground and free of other contaminating materials that could be carried into the test well.

Acceptable materials for sampling devices that may contact any groundwater sample are stainless steel, PTFE or glass. Plastics (PVC, polyethylene, or polypropylene) are an acceptable material for contacting samples when the analytes are inorganic constituents (metals, radionuclides, anions, cations) and not organic constituents. The PVC material in contact with the sample should contain only non-cemented connections and meet the requirements of NSF International's ANSI/NSF standards for well casing or potable water applications.

All sampling equipment that may contact the sample must be cleaned prior to and after each use. Pumps or bailers require cleaning of internal and external parts prior to being lowered into the well. Equipment should first be washed with clean tap water, non-phosphate detergent, and rinsed with clean tap water. Pumps may be cleaned by pumping 2 liters of the detergent solution through the pump and its suction and discharge lines followed by a clean rinse. The exterior of the pump and lines should also be cleaned with the detergent solution. A final rinse with organic-free, distilled or deionized water completes the cleaning.

Adequate isolation must be provided when there is more than one aquifer or when there is more than one sampling zone within an aquifer. In general this can be accomplished with a straddle packer pump which is comprised of a length of axial pipe upon which are mounted two packers. The fixed spacing between the packers is perforated and the pump is positioned either between the packers or above the packers. The rubber packers are expanded with air or water via surface supply lines in order to isolate a sampling zone within a bore hole or well casing. The packers are deflated to allow for vertical movement and then inflated when the desired depth is attained. Various types of sampler pump devices are available to serve as a sampler pump and may be situated as is dictated by the configuration of the well and formation.

C. Sample Container and Preservation Requirements

The certified laboratory selected to analyze the samples must be contacted to obtain appropriate instructions and sample containers. The following discussion is a general

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summary of the type and minimum size of the sample containers (provided by the KDHE laboratory), preservation requirements, and maximum holding times for the required chemical analyses. A summary of the required sample containers, preservation techniques and holding times may be found in Attachment B. Additional information may be obtained from the KDHE's Bureau of Water at (785) 296-5514. All groundwater samples shall be labeled and sealed and immediately chilled to a temperature of 40°F (4°C), then placed in coolers with securely closed lids for storage and transport. Samples must be received by the state-certified laboratory in sufficient time to conduct the requested analyses, usually within 24 hours of collection.

The following paragraphs describe specific sample container requirements as determined by the KDHE laboratory. If the containers are received from the KDHE laboratory, they will have already been properly cleaned and prepared with special cleaning solutions. Additional cleaning of the bottles should not be conducted in the field because of the possibility of sample contamination or loss of preservative. The caps of the container/bottles should be kept on at all times until sample collection.

A sample preservative will have been placed in some of the containers/bottles by the laboratory prior to shipment. This preservative is important for stabilizing the sample and preventing biological growth prior to analysis. This preservative should not be poured out or the container/bottles rinsed prior to sample collection. For some containers, the laboratory may provide the sample collector with the necessary preservative in a small vial for addition to the container after filling three quarters full with water. These preservatives are typically strong acids and extreme care should be taken to avoid contact with the skin. Eye protection should be worn. The instructions from the laboratory should be carefully followed to avoid sample invalidation.

Each sample bottle should be individually filled and recapped prior to filling another sample bottle. This will reduce the possibility of cross-contamination of one sample bottle with another via spillage or interchange of bottle caps. The samples should not be filtered in the field prior to collection. The laboratory may require the filling of additional containers for quality control purposes.

1. Metals – The sample container for metals is a 250 mL HDPE bottle with a leak-proof screw cap. It should contain a sample preservative, nitric acid, in sufficient quantity to lower the pH of the sample below 2.
2. Mineral Analyses and Miscellaneous Parameters – The sample container for the mineral analyses and miscellaneous parameters is a 1 liter cube container. A 250 mL polyethylene bottle may be substituted for the cube container. These containers should not contain a preservative.
3. Total Phosphate – The sample container for total phosphate analysis is a 250 mL high-density polyethylene amber bottle with a leak-proof screw cap. This container should contain a sulfuric acid solution for lowering the pH of the sample below 2.

4. Radionuclides

- a. The sample container for gross alpha particle activity, combined radium 226 and 228, and uranium radiological analyses is a one gallon plastic jug with a leak-proof cap. This jug should contain a small quantity of nitric acid solution to lower the pH of the sample below 2. For test well samples, there will also be a 20 mL glass vial.
- b. The sampling kit for radon should contain a faucet adaptor connected to a funnel, a syringe, a hypodermic needle and four glass vials containing 10 mL of mineral oil based liquid. A 10 cc sample is withdrawn from the volume in the funnel with the syringe. After slowly ejecting air from the syringe, place the tip of the needle at the bottom of the oil based liquid in an uncapped vial and eject the sample. After ejecting the sample remove the syringe and tightly secure the cap on the vial.

5. Volatile Organic Chemicals (VOCs) – The container provided for VOC analysis is a 40 mL glass vial. An additional vial may be provided by the laboratory for quality control purposes. Extreme care must be exercised in collecting the VOC sample. Prior to obtaining the VOC sample, the sample collector should thoroughly wash and rinse his/her hands. The VOC vial should not be opened in the presence of fuel vapors. To collect the sample, remove the cap and PTFE-lined septum (cap liner) from the vial making sure not to contaminate the inside of the cap. Contact with air and sample agitation should be minimized. If necessary, pumping rates should be significantly reduced during sampling for VOCs. Fill the vial to overflowing directly from a positive-pressure pump discharge port or bailer and place the vial on a flat surface. Float the PTFE-lined septum on top of the water in the vial, with the PTFE side (white side) in contact with the water. Screw cap on tightly, but not too tightly, since the cap will crack if excessive force is applied. Turn the vial upside down, tap lightly, and observe for air bubbles. If air bubbles are present, discard the sample. If a preservative such as hydrochloric acid or a chlorine quenching agent such as ascorbic acid has been added to the vial, discard the sample, obtain a new vial and repeat the sample collection procedure.

6. Synthetic Organic Chemicals (SOCs) – The containers for the complete SOC analysis consists of three 1 liter amber glass bottles with PTFE-lined screw caps and one 120 mL glass bottle. These bottles may contain a chlorine quenching agent. An additional bottle may be provided for laboratory quality control purposes. One of the samples collected in a 1 liter amber glass bottle should be preserved with hydrochloric acid (for analysis of PAHs, phthalates, and adipates).

D. Documentation

Once each of the sample bottles is properly filled, it should be labeled with the name of the collector, time and date of collection, sample identification number or source (e.g., test well

Appendix B: Water Quality Testing for New Public Water Supply Sources

number), PWSS name, PWSS Account Number, and other pertinent information. A sample collection form must also be completed and returned with the samples. The legal description of the test well will be pre-printed on the sample submission form and must not be changed without first contacting KDHE's Bureau of Water at 785-296-5514. Samples should be returned to the laboratory within 24 hours of sample collection. After receipt of the samples by the KDHE laboratories, test results may be reported within one to six weeks depending upon the test requested.

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Appendix B: Water Quality Testing for New Public Water Supply Sources (Attachment A)

Analytical Requirements for New Sources¹⁻⁵

Metals

Aluminum	0.05-0.2	mg/L	SMCL	
Antimony	0.006	mg/L	MCL	
Arsenic	0.010	mg/L	MCL	(Effective January 1, 2006)
Barium	2	mg/L	MCL	
Beryllium	0.004	mg/L	MCL	
Cadmium	0.005	mg/L	MCL	
Chromium	0.1	mg/L	MCL	
Mercury	0.002	mg/L	MCL	
Nickel	---	---	---	(Remanded to USEPA)
Selenium	0.05	mg/L	MCL	
Silver	0.1	mg/L	SMCL	
Thallium	0.002	mg/L	MCL	
Lead	0.015	mg/L	TT	(90th percentile Action Level)
Copper	1.3	mg/L	TT	(90th percentile Action Level)
Copper	1.0	mg/L	SMCL	
Calcium	---	mg/L	---	
Magnesium	---	mg/L	---	
Sodium	---	mg/L	---	
Iron	0.3	mg/L	SMCL	
Manganese	0.05	mg/L	SMCL	
Potassium	---	mg/L	---	
Zinc	5	mg/L	SMCL	

Mineral Analysis

Fluoride	4.0	mg/L	MCL	
Fluoride	2.0	mg/L	SMCL	
Nitrate (as N)	10	mg/L	MCL	
Nitrite (as N)	1.0	mg/L	MCL	
Chloride	250	mg/L	SMCL	
Sulfate	250	mg/L	SMCL	
pH	6.5-8.5	units	SMCL	
Specific Conductance	---	microS/cm	---	
Total Dissolved Solids	500	mg/L	SMCL	
Total Alkalinity	---	mg/L as CaCO ₃	---	
Total hardness	---	mg/L as CaCO ₃	---	
Turbidity	---	NTU	---	
Total Phosphate	---	mg/L as P	---	

Radiological Contaminants

Gross Alpha Particle (excluding uranium) Activity	15	pCi/L	MCL	
Combined Radium 226 and 228	5	pCi/L	MCL	
Uranium	30	µg/L	MCL	

Analysis for uranium required if gross alpha greater than 15 pCi/L.

Analysis for Radium 226 and 228 required for all samples.

Appendix B: Water Quality Testing for New Public Water Supply Sources (Attachment A)

Analytical Requirements for New Sources¹⁻⁵

VOCs

Method 524.2 - Volatile Organics

Benzene	0.005	mg/L	MCL
Vinyl chloride	0.002	mg/L	MCL
Carbon Tetrachloride	0.005	mg/L	MCL
1,2-Dichloroethane	0.005	mg/L	MCL
Trichloroethylene	0.005	mg/L	MCL
P-Dichlorobenzene	0.075	mg/L	MCL
1,1-Dichloroethylene	0.007	mg/L	MCL
1,1,1-Trichloroethane	0.2	mg/L	MCL
O-Dichlorobenzene	0.6	mg/L	MCL
Cis-1,2-Dichloroethylene	0.07	mg/L	MCL
Trans-1,2-Dichloroethylene	0.1	mg/L	MCL
1,2-Dichloropropane	0.005	mg/L	MCL
Ethylbenzene	0.7	mg/L	MCL
Monochlorobenzene	0.1	mg/L	MCL
Styrene	0.1	mg/L	MCL
Tetrachloroethylene	0.005	mg/L	MCL
Toluene	1	mg/L	MCL
Xylene	10	mg/L	MCL
Dichloromethane	0.005	mg/L	MCL
1,1,2-Trichloroethane	0.005	mg/L	MCL
1,2,4-Trichlorobenzene	0.07	mg/L	MCL
Chloroform (THM)	---		---
Bromodichloromethane (THM)	---		---
Bromoform (THM)	---		---
Chlorodibromomethane (THM)	---		---
Chlorobenzene	---		---
M-Dichlorobenzene	---		---
Dibromomethane	---		---
1,1-Dichloropropene	---		---
1,1-Dichloroethane	---		---
1,1,2,2-Tetrachloroethane	---		---
1,3-Dichloropropane	---		---
Chloromethane	---		---
Bromomethane	---		---
1,2,3-Trichloropropane	---		---
1,1,1,2-Tetrachloroethane	---		---
Chloroethane	---		---
2,2-Dichloropropane	---		---
O-Chlorotoluene	---		---
P-Chlorotoluene	---		---
Bromobenzene	---		---
1,3-Dichloropropene	---		---

Appendix B: Water Quality Testing for New Public Water Supply Sources (Attachment A)

Analytical Requirements for New Sources¹⁻⁵**SOCs****Method 507/508 - Chlorinated Pesticides**

Alachlor	0.002	mg/L	MCL
Atrazine	0.003	mg/L	MCL
Chlordane	0.002	mg/L	MCL
Endrin	0.002	mg/L	MCL
Heptachlor	0.0004	mg/L	MCL
Heptachlor Epoxide	0.0002	mg/L	MCL
Lindane	0.0002	mg/L	MCL
Methoxychlor	0.04	mg/L	MCL
PCBs	0.0005	mg/L	MCL
1016			
1221			
1232			
1242			
1248			
1254			
1260			
Simazine	0.004	mg/L	MCL
Toxaphene	0.003	mg/L	MCL
Hexachlorobenzene	0.001	mg/L	MCL
Hexachlorocyclopentadiene	0.05	mg/L	MCL
Aldrin	---		---
Butachlor	---		---
Dieldrin	---		---
Metolachlor	---		---
Metribuzin	---		---
Propachlor	---		---

Method 515.1 - Chlorinated Acid Pesticides

2,4-D	0.07	mg/L	MCL
2,4,5-TP	0.05	mg/L	MCL
Pentachlorophenol	0.001	mg/L	MCL
Dinoseb	0.007	mg/L	MCL
Picloram	0.5	mg/L	MCL
Dicamba	---		---

Method 525.2 - PAH's, Phthalates, Adipates

Benzo(a)pyrene	0.0002	mg/L	MCL
Di 2-Ethylhexyl Adipate	0.4	mg/L	MCL
Di 2-Ethylhexyl Phthalate	0.006	mg/L	MCL

1 MCLs established in 40 CFR Part 141.

2 SMCLs established in 40 CFR Part 143. SMCLs not enforceable.

3 "----" indicates an MCL has not been established for this parameter, but other regulatory limits or health advisories may apply.

4 Method references are contained in Methods for Determination of Organic Compounds in Drinking Water, EPA/600/4-90/020, July 1990, Environmental Systems Monitoring Laboratory, Cincinnati, OH 45268.

5 Methods utilized must be those noted above or as most recently required by USEPA.

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Appendix B: Water Quality Testing For New Public Water Supply Sources (Attachment B)

Sample Containers, Preservation Techniques, and Holding Times

Parameter Class	Container Type ¹	Preservation ²	Maximum Time from Collection to Analysis ³
Metals	250 mL narrow mouth HDPE bottle, leak-proof screw cap	Cool to 4 ° C. Nitric Acid (pH <2)	6 months
Mineral Analyses and Miscellaneous Parameters	250 mL narrow mouth HDPE bottle, leak-proof screw cap, or 1 liter cube container	Cool to 4 ° C.	28 days except for turbidity (48 hours) and total alkalinity (14 days)
Total Phosphate	250 mL HDPE amber bottle with leak-proof screw cap	Sulfuric Acid (pH < 2)	28 days
Gross Alpha, Radium 226 and 228, and Uranium	1 gallon plastic jug with leak-proof screw cap; and 20 mL glass vial (test well)	Nitric Acid (pH < 2) (jug only)	6 months
Radon	20 mL glass vial with leak-proof cap	10 mL mineral oil based liquid	4 days
Volatile Organic Chemicals (Method 524.2)	40 mL glass vial, PTFE-lined silicone septum, leak-proof screw cap with hole	Cool to 4 ° C. Hydrochloric Acid (pH < 2)	14 days
Chlorinated Pesticides (Method 507/508)	1 liter amber glass bottle, PTFE-lined air-tight screw cap	Cool to 4 ° C.	7 days until extraction 14 days after extraction
Chlorinated Acid Pesticides (Method 515.1)	1 liter amber glass bottle, PTFE-lined air-tight screw cap	Cool to 4 ° C.	14 days until extraction 28 days after extraction
PAHs, Phthalates, Adipates (Method 525.2)	1 liter amber glass bottle, PTFE-lined air-tight screw cap	Cool to 4 ° C. Hydrochloric Acid (pH<2)	7 days until extraction 30 days after extraction
Carbamates ⁴ (Method 531.1)	120 mL glass bottle, PTFE-lined silicone septum, air-tight screw cap with hole	Cool to 4 ° C. Chloroacetic Acid Buffer	28 days

¹ Laboratory may request additional containers be filled and returned for quality control purposes.

² If residual chlorine will be present in a sample, the laboratory may require the addition of quenching agents. These agents may include: ascorbic acid powder (VOCs), sodium thiosulfate (carbamates), and sodium sulfite (PAHs, pesticides, phthalates, adipates).

³ Times refer to maximum time allowable between sample collection and sample procedure by laboratory for analysis to be valid. Sample collector, however, should transport samples to the laboratory as soon as possible. Laboratory should receive containers within 24 hours of sample collection.

⁴ Carbamate analysis presently waived by KDHE Laboratory.

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APPENDIX C

PROCEDURES FOR PRESSURE AND LEAKAGE TESTING OF WATER MAINS

All newly installed mains must be pressure and leakage tested prior to final acceptance. This memorandum provides recommended standards for pressure and leakage testing ductile iron and PVC water mains. These recommendations closely follow relevant AWWA Standards and industry specifications. The applicable AWWA Standards are C600 for ductile iron mains and C605 for PVC mains, or their most recent revision. Industry specifications for PVC pipe are from Uni-Bell PVC Pipe Association's handbook (Uni-Bell, 2001) and installation guide (Uni-Bell, 2004), and from DIPRA's installation guide for DIP (DIPRA, 2003). Pressure and leakage testing requirements for materials other than ductile iron or PVC will be determined on a case-by-case basis. Alternate pressure and leakage criteria for ductile iron or PVC mains are acceptable provided they are shown to be at least as stringent as the criteria presented in this memorandum or most recent revision of applicable AWWA Standards.

Simultaneous or separate pressure and leakage tests may be performed. The test durations and pressures for each option are specified in Table 1. If separate tests are made, the pressure test should be conducted prior to the leakage test.

TABLE 1 - PRESSURE AND LEAKAGE TEST METHODS

Procedure	Test Pressure	Duration of Test
Simultaneous Pressure & Leakage Test	150% of working pressure* at point of test, but not less than 125% of normal working pressure at highest elevation.	2 Hours
Separate Pressure Test	150% of working pressure* at point of test, but not less than 125% of normal working pressure at highest elevation.	1 Hour
Separate Leakage Test	150% of working pressure* of segment tested.	2 Hours

* Working pressure is defined as the maximum anticipated sustained operating pressure. However, in no case shall the test pressure exceed the pressure rating for the pipe, valves, appurtenances, or thrust-restraints.

Pressure Test

The purpose of the pressure test is to locate defects in materials or workmanship. Before testing, the pipeline must be backfilled and braced sufficiently to prevent movement under pressure.

Appendix C: Procedures for Pressure and Leakage Testing of Water Mains

If concrete thrust blocks are used, sufficient time must be allowed before testing to ensure that the concrete has cured sufficiently. The test ends also should be restrained to withstand thrusts potentially developed under the test pressures.

A pressure test should be conducted at 150% of the working pressure in the line. The working pressure is defined as the maximum anticipated sustained operating pressure in the line being tested. Care must be taken not to exceed the pressure rating of pipes, valves, fittings, thrust restraints, or other appurtenances. Pressures in the main may exceed the specified test pressure if the water pressure is read from a gauge located at a high point in the main.

Potable water is introduced into the main through a temporary connection to a hydrant, corporation stop in the new main, or valved connection with the existing line. While filling the new main, air must be expelled from the pipeline by venting through service connections, hydrants, or air-release valves. Corporation stops may be required at high points in the line if there are insufficient valves to release air from the main. It is important to completely expel air from each section of the main to be tested. Compressed entrapped air may amplify surges within the main or cause erroneous pressure test results.

After filling the main with water and expelling air, a pump is utilized to increase the water pressure within the line up to the required test pressure and to maintain that pressure for the required duration (See Table 1). An accurate method for measuring the amount of water pressure within the line must be provided. A key criterion for the pressure test is that the measured water pressure within the main (after reaching the required test pressure) should not vary by more than 5 psi during the duration of the test. While the line is under pressure, the system and all exposed pipe, fittings, valves, and hydrants should be examined for leakage. Any damaged or defective pipe, fittings, valves, hydrants, or joints should be repaired or replaced and the pressure test repeated until satisfactory results are obtained.

Leakage Test

The purpose of the leakage test is to establish that the section of main being tested, including all joints, fittings and other appurtenances, will not leak or that leakage is within acceptable limits. If the leakage test is to be performed simultaneously with the pressure test, the system should be allowed to stabilize at the test pressure before conducting the leakage test.

Equipment necessary for conducting the leakage test includes a pump equipped with a make-up reservoir and a pressure gauge for measuring water pressure in the main. In addition, there must be an accurate method for measuring the quantity of water pumped into the main being tested. Methods used to measure water volume include a calibrated make-up reservoir, a calibrated positive-displacement pump, or a water meter.

The specified test pressure for the leakage test is the same as for the pressure test (See Table 1) and the test should be conducted for at least 2 hours in duration. Leakage is defined as the quantity of water that must be supplied into the main in order to maintain the water pressure within 5 psi of the specified test pressure after the pipe has been filled with water and air expelled. No pipe

Appendix C: Procedures for Pressure and Leakage Testing of Water Mains

installation will be acceptable if the leakage is greater than that determined by the following formulas:

For PVC or DIP pipe,

$$L = \frac{SD\sqrt{P}}{148,000}$$

where,

- L = allowable leakage, in gallons per hour
- S = length of pipe tested, in feet
- D = nominal diameter of the pipe, in inches
- P = average test pressure during the leakage test, in pounds per square inch

The above equation is based on a leakage rate of 10.5 gallons per day per mile per inch of nominal diameter of pipe. Leakage values determined by the above formula for 1000 feet of pipe are presented in Table 2. These values are similar to those presented in AWWA C605 and DIPRA (DIPRA, 2003).

TABLE 2 - ALLOWABLE LEAKAGE (gal/hr) FOR 1000 FT OF GASKETED PVC OR DIP PIPE

Nominal Pipe Size (in)	Average Test Pressure in Pipeline, psi													
	50	75	100	125	150	175	200	225	250	275	300	350	400	450
2	0.10	0.12	0.14	0.15	0.17	0.18	0.19	0.20	0.21	0.22	0.23	0.25	0.27	0.29
3	0.14	0.18	0.20	0.23	0.25	0.27	0.29	0.30	0.32	0.34	0.35	0.38	0.41	0.43
4	0.19	0.23	0.27	0.30	0.33	0.36	0.38	0.41	0.43	0.45	0.47	0.51	0.54	0.57
6	0.29	0.35	0.41	0.45	0.50	0.54	0.57	0.61	0.64	0.67	0.70	0.76	0.81	0.86
8	0.38	0.47	0.54	0.60	0.66	0.72	0.76	0.81	0.85	0.90	0.94	1.01	1.08	1.15
10	0.48	0.59	0.68	0.76	0.83	0.89	0.96	1.01	1.07	1.12	1.17	1.26	1.35	1.43
12	0.57	0.70	0.81	0.91	0.99	1.07	1.15	1.22	1.28	1.34	1.40	1.52	1.62	1.72
14	0.67	0.82	0.95	1.06	1.16	1.25	1.34	1.42	1.50	1.57	1.64	1.77	1.89	2.01
16	0.76	0.94	1.08	1.21	1.32	1.43	1.53	1.62	1.71	1.79	1.87	2.02	2.16	2.29
18	0.86	1.05	1.22	1.36	1.49	1.61	1.72	1.82	1.92	2.02	2.11	2.28	2.43	2.58
20	0.96	1.17	1.35	1.51	1.66	1.79	1.91	2.03	2.14	2.24	2.34	2.53	2.70	2.87
24	1.15	1.40	1.62	1.81	1.99	2.15	2.29	2.43	2.56	2.69	2.81	3.03	3.24	3.44
30	1.43	1.76	2.03	2.27	2.48	2.68	2.87	3.04	3.21	3.36	3.51	3.79	4.05	4.30
36	1.72	2.11	2.43	2.72	2.98	3.22	3.44	3.65	3.85	4.03	4.21	4.55	4.86	5.16
42	2.01	2.46	2.84	3.17	3.48	3.75	4.01	4.26	4.49	4.71	4.92	5.31	5.68	6.02
48	2.29	2.81	3.24	3.63	3.97	4.29	4.59	4.86	5.13	5.38	5.62	6.07	6.49	6.88
54	2.58	3.16	3.65	4.08	4.47	4.83	5.16	5.47	5.77	6.05	6.32	6.83	7.30	7.74
60	2.87	3.51	4.05	4.53	4.97	5.36	5.73	6.08	6.41	6.72	7.02	7.58	8.11	8.60
64	3.06	3.75	4.32	4.83	5.30	5.72	6.12	6.49	6.84	7.17	7.49	8.09	8.65	9.17

Note: The allowable leakage for test sections with different diameters is the sum of the computed leakage for each pipe size.

Appendix C: Procedures for Pressure and Leakage Testing of Water Mains

When testing against closed metal seated valves, an additional leakage per closed valve of 0.0078 gal/hr/in of nominal valve size is allowed.

Leakage less than the quantity specified by the above equation may be considered "allowable leakage" resulting from such factors as trapped air, take-up of restraints, and temperature variations during testing. However, observed leaks should be repaired regardless of leakage measurements through metering equipment.

A swift loss of water pressure in the main could be the result of a break in the line, major valve opening, loose mechanical joint bolts, missing or dislodged gasket, or inadequate thrust block. A slow loss of pressure in excess of allowable limits could be the result of minor problems such as a leaking valve or a corporation stop not completely shut off. In addition, air entrapped in the line can result in an apparent leakage in excess of the allowable limit.

Recommendations for avoiding minor leaks include the following:

1. Vent all high points in the line by use of air release valves or corporation stops.
2. Check all mechanical joint bolted connections.
3. Cure thrust blocks before testing.
4. Insure that exposed gasket grooves are properly cleaned before inserting gaskets.
5. When inserting pipe into a mechanical joint or gasket joint, insure that the spigot end is squarely cut and beveled properly for the hub.

One approach for determining if the apparent leakage is the result of air entrapped in a line is to immediately repeat the leakage test (i.e., continue the test for another two hours) and determine the amount of make-up water required to fill the line a second time. If this amount is significantly less than the first filling, the difference in apparent leakage is probably the result of air being present in the line. If no significant difference in make-up water is recorded, a leak is probable.

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APPENDIX D

PROCEDURES FOR THE DISINFECTION OF WATER MAINS

All new or repaired potable water lines in a public water supply system must be disinfected with free chlorine before they are put into service (KAR 28-15-18(d)). These disinfection procedures are based on the AWWA Standard for Disinfecting Water Mains, AWWA C651. The most recent revision of the standard shall apply. A copy of the complete standard is available for review at the KDHE office, Curtis State Office Building, 1000 Jackson St., Suite 420, Topeka, KS. A copy of the standard may be obtained from the American Water Works Association, 6666 West Quincy Avenue, Denver, Colorado, 80235.

NON-EMERGENCY PROCEDURES FOR THE DISINFECTION OF WATER MAINS

There are five basic steps for the non-emergency disinfection of water mains. The first step is to protect the water main's sanitary condition. It is always best to prevent the introduction of contaminated material into water main pipe, especially during its installation. However, whenever this is not possible, any contamination that does occur must be either flushed from the water main or removed by other more direct methods prior to disinfection. When the water main has been adequately cleared, it may then be disinfected by either the tablet, continuous or slug method of disinfection. These methods disinfect by maintaining a minimum period of contact between the water main and the disinfecting solution prepared and delivered as prescribed below for each method. In addition, each method requires flushing of the heavily chlorinated disinfecting solution followed by its proper disposal in a manner that does not adversely impact the environment. The final step consists of collecting samples from the water main for bacteriological testing as a means to confirm the effectiveness of the disinfection procedure. While this method of confirmation is not required, KDHE strongly recommends that this final step be completed.

Step 1: Preventative Measures During Construction

During construction, the interior as well as all sealing surfaces of pipes, fittings, and accessories should be kept clean as possible. Inspect the interior of all pipes prior to installation. If dirt enters the pipe, it should be removed and the affected interior of the pipe swabbed with a 1 percent free available chlorine solution. All openings in pipelines should be closed with watertight plugs whenever the trench is unattended. Sealing, lubricating, or gasket materials used in pipe installation should be stored and handled in a manner that avoids contamination and keeps them suitable for use with potable water.

Step 2: Preliminary Flushing of Mains

Before being chlorinated, the main should be completely filled with water to eliminate air pockets and then flushed to purge the line of dirt and debris. This is typically done after the completion of the leakage and pressure tests. Incomplete removal of dirt and debris from lines prior to disinfection often leads to failed bacteriological tests, requiring repeated disinfection. Preliminary

Appendix D: Procedures for the Disinfection of Water Mains

flushing should be accomplished at a rate of at least 2.5 ft/sec. Fittings and valves should be thoroughly cleaned before applying chlorine to a main. Special attention should be given to mechanical joints, fittings, and valves that may contain spaces that are difficult to chlorinate once they become filled with water.

Table 1 shows the required flow rate to obtain a velocity of 2.5 ft/sec in commonly used sizes of pipe. Flushing can be enhanced by the use of soft pigs to remove dirt, debris, and air from the main prior to disinfection. The use of pigs can also conserve water and is particularly useful when there is insufficient water supply to attain a 2.5 ft/sec minimum flushing velocity.

TABLE 1 - FLOWS REQUIRED FOR VARIOUS FLUSHING VELOCITIES

Pipe Size (in)	Pipe Area (sq ft)	Flow Required (gpm) for Given Velocity		
		1 ft/sec	2.5 ft/sec	5 ft/sec
2	0.02	10	25	50
4	0.09	40	100	200
6	0.20	90	220	440
8	0.35	155	390	780
10	0.55	245	610	1,220
12	0.79	350	880	1,760
14	1.07	480	1,200	1,400
16	1.40	625	1,570	3,140

Preliminary flushing, however, should not be conducted if tablets or granules of calcium hypochlorite have been placed in the pipe during installation. In this case, special care must be exercised in ensuring that the main does not become contaminated with dirt or other materials during construction.

Step 3: Chlorination of Mains

Disinfection of mains should be done only by crews who have had experience with chlorinating agents, who are aware of the potential health hazards associated with these chemicals, and who are trained to carefully observe proper construction and disinfection practices.

Chemical Forms of Chlorine

Chlorine is generally available in three chemical forms: gaseous (elemental) chlorine (shipped as a liquefied gas); in solution (sodium hypochlorite); and as a solid (calcium hypochlorite tablets or

Appendix D: Procedures for the Disinfection of Water Mains

granules). The gaseous form may only be applied with feed systems that operate under vacuum, the solution form is generally diluted, and the solid form must be dissolved.

A. Gaseous Chlorine

Gaseous chlorine is generated from the controlled vaporization of liquid chlorine supplied in 100 or 150-lb steel cylinders through a vacuum-operated chlorinator with a booster pump. The vacuum-operated chlorinator injects chlorine gas into water to form a solution; the booster pump introduces the solution into the main to be disinfected. Direct-feed chlorinators, which operate solely from gas pressure in the chlorine cylinder, are not approved for use due to the danger of chlorine release. Gaseous chlorine application should only be conducted under the direct supervision of a trained operator and in accordance with the safety standards and practices described in Chapter IX of KDHE's "Policies, General Considerations and Design Requirements for Public Water Supply Systems in Kansas."

B. Sodium Hypochlorite

Sodium hypochlorite is available as a liquid in 1 quart to 5 gallon containers and contains approximately 5 to 15 percent available chlorine. ANSI/NSF 60 certified household bleaches typically contain approximately 5.25 percent available chlorine. The availability of household bleaches having NSF International's ANSI/NSF 60 certification varies from market to market. Special precautions must be taken to minimize deterioration of sodium hypochlorite solutions in storage.

C. Calcium Hypochlorite (HTH)

Calcium hypochlorite (HTH) is available in granular and tablet forms typically containing approximately 65 percent available chlorine. The granules dissolve readily in water; however, the tablets can be more difficult to dissolve. In contrast to sodium hypochlorite, calcium hypochlorite can be stored for extended periods of time without significant deterioration. Contact with organic material or high temperatures must be avoided due to the danger of fire or explosion.

Methods of Chlorination

AWWA Standard C651 provides for three methods of chlorination for water mains: tablet, continuous, and slug. The chlorine dose and minimum contact time for each AWWA method are summarized in Table 2. Recommendations for disinfection of small sections of mains under emergency repair are also included in Table 2. Methods for measurement of free chlorine residual are summarized in Attachment A. Before any disinfection method is utilized, valves must be positioned so that the highly chlorinated water in the main being treated does not flow into water mains that are in active service.

Appendix D: Procedures for the Disinfection of Water Mains

TABLE 2 - CHLORINATION METHODS FOR DISINFECTING WATER MAINS

Chlorination Method Used	Initial Chlorine Dose (mg/L)	Minimum Contact Time (hours)	Minimum Chlorine Resid. (mg/L)
Nonemergency Procedures			
Tablet	25	24	10
Continuous	25	24	10
Slug	100	3	50
Emergency Procedures			
Premixed Solution or Hypochlorite Injection	300	0.25	100
Swabbing	10,000 (1% sol)	---	Swab throughly the interior of pipes and fittings used in repairs.

Factors to consider when choosing a method of chlorination include length and diameter of the main, types of joints present, equipment and materials necessary for disinfection, skills and training of personnel, safety concerns, and if the main must be quickly put into service. The continuous and slug methods require the use of appropriate chlorine feed equipment and the determination of the necessary chlorine feed rate for the chlorine solution. In long, large-diameter mains, the slug method has the potential for reducing the volume of water and amount of chemicals needed as compared to the continuous method.

The tablet method is convenient to use for mains with diameters less than 24 inches and does not require special chlorine feed equipment. There are, however, important limitations with this method. The tablet method precludes preliminary flushing which is often necessary to remove dirt and debris and assist in the removal of air from the lines. Calcium hypochlorite granules or tablets may be dislodged from the lines during filling and accumulate at points of restriction leaving portions of the line without disinfectant. The tablet method should not be used in large diameter mains, where a worker might enter the main for inspection, due to the potential for tablets to release toxic fumes.

A. Tablet Method

The tablet method consists of pre-placing calcium hypochlorite granules or tablets in the main during pipe installation in sufficient amounts so as to obtain a 25 mg/L available chlorine dose. For calcium hypochlorite granules, they should be placed at the upstream end of the first section of pipe, at the upstream end of each branch main, and at 500 ft.

Appendix D: Procedures for the Disinfection of Water Mains

intervals. Additionally, one tablet should be placed in each hydrant, hydrant branch, and other appurtenances. For 65 percent available chlorine, the quantities of granules necessary for a 25 mg/L chlorine dose are listed in Table 3 as a function of pipe diameter.

**TABLE 3 - AMOUNTS OF CALCIUM HYPOCHLORITE GRANULES
TO BE PLACED AT 500-ft INTERVALS FOR 25 mg/L
FREE CHLORINE DOSE**

Pipe Diameter (in)	Calcium Hypochlorite Granules (65% available)	
	(ounces)	(grams)
2	0.4	12
4	1.7	47
6	3.8	107
8	6.7	190
10	10.5	297
12	15.1	427
16	26.8	760

Adapted from AWWA Standard C651-05

Calcium hypochlorite granules should not be placed in the pipe so as to come in contact with exposed joint compounds, such as those used on solvent-welded plastic pipe, because of the danger of fire or explosion from the reaction of the joint compound with the calcium hypochlorite.

Instead of granules, calcium hypochlorite 5-g tablets can be attached with a food-grade adhesive to the top inside surface of each section of the main's pipe. Table 4 shows the number of 5-g tablets required for commonly used pipe sizes.

After installation is complete, the main should be filled with potable water at a velocity no greater than 1 ft/sec (See Table 1 for flow rates corresponding to 1 ft/sec velocity for standard pipe sizes.). The chlorinated water must be maintained in the main for at least 24 hours. If the water temperature is less than 41°F (5°C), the water should remain in the pipe for at least 48 hours. At the end of the minimum contact period, the treated water in all portions of the main must have a residual of not less than 10 mg/L free chlorine as confirmed by measurement of the chlorine residual. Methods utilized to measure free chlorine residual are discussed in Attachment A.

**TABLE 4 - NUMBER OF 5-g CALCIUM HYPOCHLORITE TABLETS
REQUIRED FOR DOSE OF 25 mg/L***

Pipe Diameter (in)	Length of Pipe Section, ft				
	13 or less	18	20	30	40
Number of 5-g Calcium Hypochlorite Tablets					
2	1	1	1	1	1
4	1	1	1	1	1
6	1	1	1	2	2
8	1	2	2	3	4
10	2	3	3	4	5
12	3	4	4	6	7
16	4	6	7	10	13

*Based on 3.25-g available chlorine per tablet; any portion of tablet rounded to the next highest integer. (Adapted from AWWA Standard C651-05)

B. Continuous Method

Though this method is referred to as “continuous,” it does not require continuous feeding of chlorine into the main over a 24 hour period. The key feature is that the main is “continuously” in contact with at least 10 mg/L free chlorine concentration over 24 hours with an initial dose of 25 mg/L. Two procedures will be outlined below.

Procedure 1: Addition of Pre-mixed Chlorinated Water

In this procedure, hypochlorite is added to potable water in a tanker truck or other large container in sufficient volume to completely fill the main with a chlorine residual of 25 mg/L. The chlorinated water from the tanker truck or large container is then pumped into the main until full as indicated by a discharge through a terminal outlet such as a hydrant. The addition of premixed chlorinated water to the main does not require the feeding of a concentrated chlorine solution or the measurement and control of the filling rate and the chlorine solution injection rate.

The minimum amount of calcium hypochlorite (HTH) required for a 25 mg/L chlorine dose can be calculated from the known volume of the main that is to be disinfected:

Appendix D: Procedures for the Disinfection of Water Mains

$$\frac{\text{Vol}_{\text{main, gal}} * \frac{1 \text{ MG}}{1 \times 10^6 \text{ gal}} * 8.34 \frac{\text{lb}}{\text{gal}} * 25 \frac{\text{mg}}{\text{L}}}{\frac{(\% \text{ available Cl}_2)}{100}} = \text{minimum lbs of HTH available} \quad (\text{Eq. 1})$$

where,

$$\begin{aligned} \text{Vol}_{\text{main}} &= \text{volume of main, gal} \\ &= \text{length(ft)} * \pi[\text{dia(ft)}]^2/4 * 7.48 \text{ gal/ft}^3 \end{aligned}$$

Please note that the units in the above equation (Eq. 1) will correctly cancel provided one recognizes that there are one million mg in one liter (10^6 mg/liter) and that % available $\text{Cl}_2/100$ is equal to lbs of chlorine per lb of HTH (lb $\text{Cl}_2/\text{lb HTH}$).

The following equation determines the necessary amount of sodium hypochlorite to achieve a 25 mg/L chlorine main:

$$\frac{\text{Vol}_{\text{main}} * 25 \frac{\text{mg}}{\text{L}}}{\text{Conc}_{\text{soln}} \frac{\text{mg}}{\text{L}}} = \text{Vol}_{\text{soln}} \quad (\text{Eq. 2})$$

where,

$$\begin{aligned} \text{Vol}_{\text{main}} &= \text{volume of main, gal} \\ \text{Conc}_{\text{soln}} &= \text{concentration of chlorine in sodium hypochlorite solution, mg/L as Cl}_2 \\ \text{Vol}_{\text{soln}} &= \text{volume of sodium hypochlorite solution, gal} \end{aligned}$$

The quantities of 15 percent available chlorine sodium hypochlorite or 65 percent available chlorine calcium hypochlorite (HTH) required to produce a 25 mg/L concentration in water filling a section of main with a length of 100 ft. in common diameters are shown in Table 5.

Procedure 2: Injection of Concentrated Chlorine Solution

An alternate approach is to inject a concentrated chlorine solution into the main while it is being filled. The contractor or operator maintains a desired water flow rate while filling the main through an inlet valve on a temporary connection to the existing distribution system or other approved source. At a point no more than 10 ft. downstream from the inlet to the main, the concentrated chlorine solution is pumped into the main at a uniform feed rate until the desired chlorine residual (at least 25 mg/L) is measured in the flushed water at the terminal outlet (Figure 1). The main is then shut down and the chlorinated water allowed to stand in the pipe for a 24 hour period. At the end of this time period, the treated water in the main should have a chlorine residual of not less than 10 mg/L free chlorine in all portions of

Appendix D: Procedures for the Disinfection of Water Mains

the main as confirmed by the measurement of the chlorine residual in samples collected from the main. Methods utilized to measure free chlorine residual are discussed in Attachment A.

**TABLE 5 - HYPOCHLORITE REQUIRED TO PRODUCE
25-mg/L DOSE IN 100 ft OF PIPE**

		Hypochlorite Solution				Granules
Pipe Size (in)	Total Pipe Volume (gal)	Percent Available Chlorine				
		1-percent (gal)	5-percent (gal)	10-percent (gal)	15-percent (gal)	65-percent (ounces)
2	16.3	0.041	0.0082	0.0041	0.0027	0.084
4	65.3	0.16	0.033	0.016	0.011	0.34
6	147	0.37	0.073	0.037	0.024	0.75
8	261	0.65	0.13	0.065	0.044	1.3
10	408	1.02	0.20	0.10	0.068	2.1
12	587	1.47	0.29	0.15	0.098	3.0
16	1044	2.61	0.52	0.26	0.17	5.4

Note: 1-percent chlorine solution = 10,000 ppm or mg/L free chlorine.

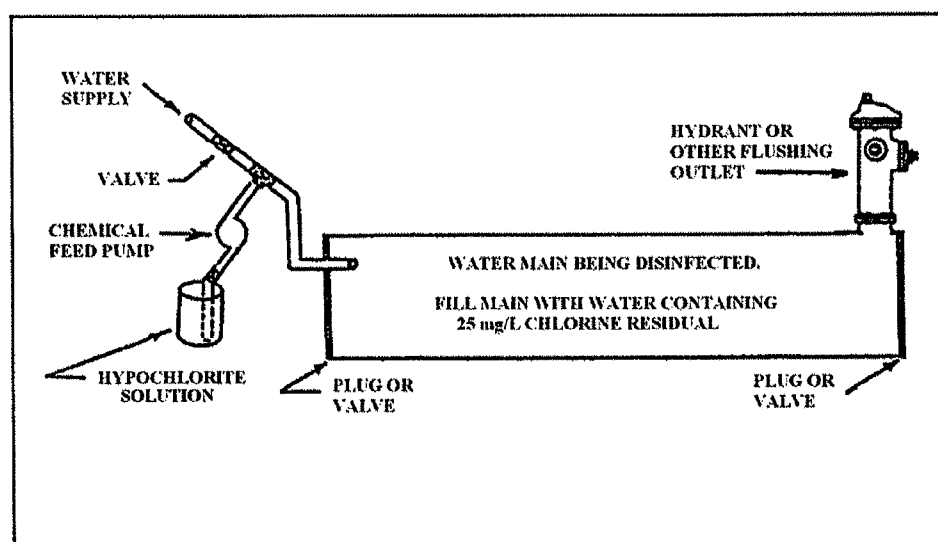


Figure 1 - TYPICAL HYPOCHLORITE INJECTION SYSTEM

Appendix D: Procedures for the Disinfection of Water Mains

The concentrated chlorine solution may be prepared from calcium or sodium hypochlorite and injected into the main with a chemical feed pump designed for chlorine solutions. While this is readily accomplished with sodium hypochlorite because it is purchased as a liquid, calcium hypochlorite in the form of HTH granules or tablets must first be dissolved in water. It is important to remember that the HTH granules or tablets should be added to the correct volume of water in order to adequately disperse the heat generated during dissolution, rather than adding water to the HTH granules or tablets. Feed lines and connections should be of such material and strength as to safely withstand the corrosive effect of the concentrated chlorine solution and the pressure of the pump. The flows of both the water filling the main and the concentrated chlorine solution being injected must be proportioned so that the resulting chlorine concentration in the main is uniform and at least 25 mg/L (Figure 2).

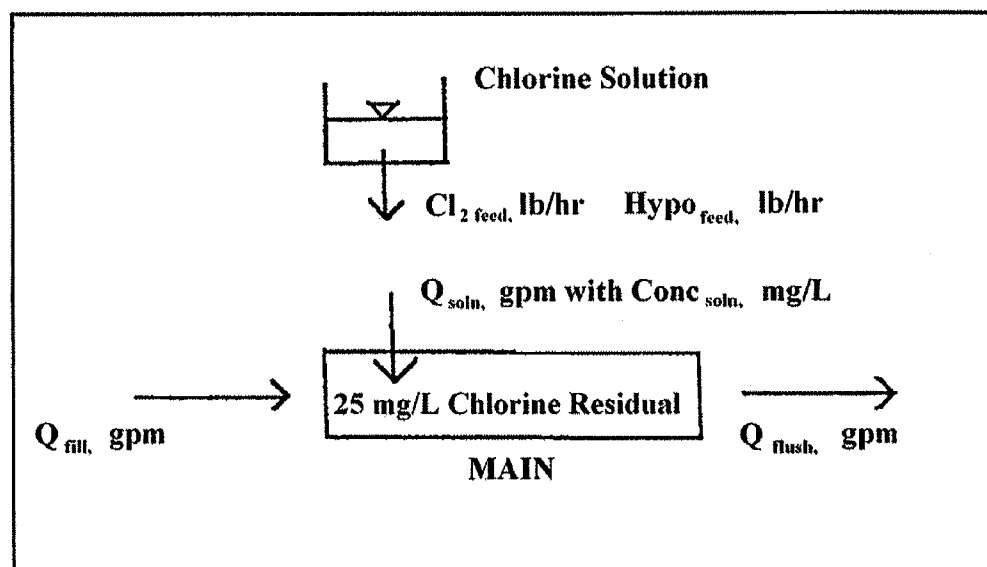


Figure 2 - MASS BALANCE DIAGRAM FOR Cl_2 SOLUTION INJECTION

In most cases, the chlorine solution injection rate, Q_{soln} , will be significantly less than the rate of filling the main, Q_{fill} . When this is true, Q_{fill} may be considered essentially equivalent to the rate of water exiting the main, Q_{flush} . After startup of the chlorine solution injection, the chlorine residual should be checked at the first available outlet, and the hypochlorite injection rate adjusted to obtain a residual of at least 25 mg/L.

This approach, the injection of a concentrated chlorine solution into a flowing main, is consistent with the typical chlorination procedure used by operators in disinfecting a continuous flow of water from a well using a hypochlorite feed system. It does, however, require maintaining a specific main filling rate (or flushing rate from the outlet of the pipe)

as well as a uniform chlorine solution injection rate. Flow rates may be difficult to measure accurately under field conditions that typically involve temporary connections. In addition to the use of flow meters, methods for estimating flow rates include measuring the time to fill a container of known volume or measuring the trajectory of the discharge from a hydrant and using the formula in Figure 3 to determine the flow rate.

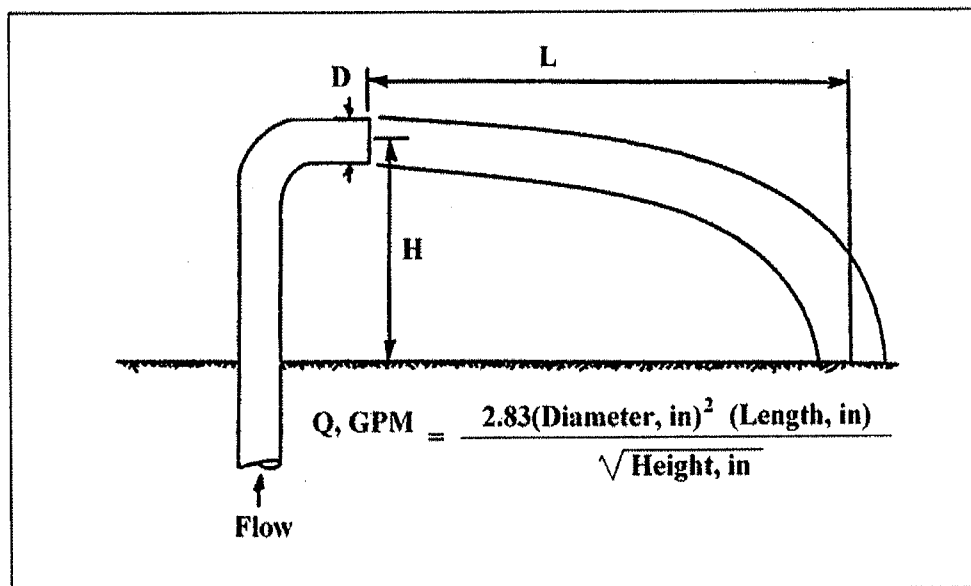


Figure 3 - FORMULA FOR ESTIMATING RATE OF DISCHARGE
 Reproduced from *Water Distribution System Operation and Maintenance: A Field Study Training Program*, 5th ed. (2005), with permission. Copyright by the California State University, Sacramento Foundation.

The chlorine feed rate into the main, $\text{Cl}_2 \text{ feed}$, for a 25 mg/L dose (assuming 100 percent available chlorine such as supplied by chlorine gas) may be calculated with the following equation:

$$Q_{\text{fill}}, \frac{\text{gal}}{\text{min}} * 1440 \frac{\text{min}}{\text{day}} * \frac{1 \text{ day}}{24 \text{ hr}} * \frac{1 \text{ MG}}{1 \times 10^6 \text{ gal}} * 8.34 \frac{\text{lb}}{\text{gal}} * 25 \frac{\text{mg}}{\text{L}} = \text{Cl}_2 \text{ feed}, \frac{\text{lb}}{\text{hr}} \quad (\text{Eq. 3})$$

where,

Q_{fill} = flow rate of water filling main, gpm

$\text{Cl}_2 \text{ feed}$ = chlorine feed rate into main, lbs of Cl_2 as 100% available chlorine /hr

Appendix D: Procedures for the Disinfection of Water Mains

In chlorine feed rate problems, the chlorine solution injection rate, Q_{soln} , and the filling rate of the main, Q_{fill} , are typically assumed and fixed. Where the chlorine solution is applied uniformly to the main while it is filling, the time of filling of the main, T_{fill} , is essentially equivalent to the time of chlorine solution injection, $T_{\text{injection}}$:

$$\frac{\text{Vol}_{\text{main, gal}}}{Q_{\text{fill, min}}} = T_{\text{fill, min}} = T_{\text{injection, min}} \quad (\text{Eq. 4})$$

where,

Vol_{main} = volume of main, gal

Q_{fill} = main filling rate, gpm

T_{fill} = time to fill main, min

$T_{\text{injection}}$ = time of chlorine solution injection, min

The minimum volume of chlorine solution, prepared from either sodium or calcium hypochlorite, may be determined by multiplying the chlorine solution injection rate by the time of chlorine solution injection:

$$Q_{\text{soln, min}} * T_{\text{injection, min}} = \text{Vol}_{\text{soln, gal}} \quad (\text{Eq. 5})$$

where,

Q_{soln} = rate of chlorine solution injection, gpm

$T_{\text{injection}}$ = time of chlorine solution injection, min

Vol_{soln} = volume of chlorine solution, gal

Utilization of Calcium Hypochlorite (HTH)

When calcium hypochlorite is utilized to prepare a concentrated chlorine solution for this second procedure, the chlorine solution feed rate, $\text{Cl}_2 \text{ feed}$ (lb/hr) (Eq. 3), can be converted to a calcium hypochlorite feed rate (HTH), HTH_{feed} (lb/hr) by use of the following equation:

$$\frac{\text{Cl}_2 \text{ feed, lb/hr}}{(\% \text{ available Cl}_2)} = \text{HTH}_{\text{feed, lb/hr}} \quad (\text{Eq. 6})$$

The total lbs of calcium hypochlorite required for disinfecting a given main are determined by multiplying HTH_{feed} , (lb/hr) by the injection time, $T_{\text{injection}}$, expressed in units of hours or by solving Eq. 1 above:

Appendix D: Procedures for the Disinfection of Water Mains

$$\text{HTH}_{\text{feed}} \cdot \frac{\text{lb}}{\text{hr}} \cdot T_{\text{injection}} \cdot \text{hr} = \text{minimum required HTH, lbs} \quad (\text{Eq. 7})$$

where,

HTH_{feed} = calcium hypochlorite feed rate, lb/hr
 $T_{\text{injection}}$ = time of chlorine solution injection, hr

The concentration of the chlorine solution, prepared by the addition of the required lbs of HTH to the necessary volume of water, Vol_{soln} (Eq. 5), may be calculated by use of the following equation:

$$\frac{\text{lbs of HTH}}{\text{Vol}_{\text{soln}} \cdot \text{gal}} \cdot \frac{(\% \text{ available Cl}_2)}{100} \cdot \frac{1 \times 10^6}{1 \text{ MG}} \cdot \frac{1 \frac{\text{mg}}{\text{L}}}{8.34 \frac{\text{lb}}{\text{MG}}} = \text{Conc}_{\text{soln}} \cdot \frac{\text{mg}}{\text{L}} \quad (\text{Eq. 8})$$

where,

Vol_{soln} = volume of chlorine solution, gal
 $\text{Conc}_{\text{soln}}$ = chlorine concentration in injected solution, mg/L as Cl_2

Utilization of Sodium Hypochlorite Solution

A concentrated sodium hypochlorite solution may also be utilized for this second procedure. Sodium hypochlorite is available in liquid form as a concentrated chlorine solution expressed typically in percent available chlorine where 1 percent available chlorine is approximately equivalent to 10,000 mg/L chlorine. Strong solutions of sodium hypochlorite, such as 15 percent, may be injected directly into a flowing main with a chemical feed pump without the necessity of dilution. In such cases, the concentration of chlorine in the injected solution is known. For an assumed sodium hypochlorite solution injection rate, Q_{soln} , the filling rate of the main, Q_{fill} , can be determined from the following equation:

$$\frac{Q_{\text{soln}} \cdot \text{Conc}_{\text{soln}} \cdot \frac{\text{mg}}{\text{L}}}{25 \frac{\text{mg}}{\text{L}}} - Q_{\text{soln}} = Q_{\text{fill}} \quad (\text{Eq. 9})$$

where,

Q_{soln} = rate of sodium hypochlorite solution injection, gpm
 $\text{Conc}_{\text{soln}}$ = chlorine concentration in injected solution, mg/L as Cl_2
 Q_{fill} = main filling rate, gpm

Appendix D: Procedures for the Disinfection of Water Mains

Table 5 includes the minimum volumes of various sodium hypochlorite solutions (1%, 5%, 10%, and 15%) for direct injection into a 100 ft. main to prepare a 25 mg/L chlorine dose. Eq. 2 above may also be used to calculate the required volume of chlorine solution as sodium hypochlorite for a given Vol_{main} , Q_{fill} , and Q_{soln} . For a given Q_{fill} , Eq. 3 above may be utilized to calculate the necessary chlorine feed rate into the main, which is converted to a sodium hypochlorite feed rate by the following equation:

$$\frac{Cl_2 \text{ feed, } \frac{lb}{hr}}{(\% \text{ available } Cl_2)} = Na - \text{hypo}_{\text{feed}}, \frac{lb}{hr} \quad (\text{Eq. 10})$$

where,

$Cl_2 \text{ feed}$ = chlorine feed rate into main, lbs of Cl_2 as 100% available chlorine /hr

$Na\text{-hypo}_{\text{feed}}$ = rate of sodium hypochlorite solution injection, lb/hr

If a flow rate in gal/hr is more convenient, then the sodium hypochlorite feed rate can be determined by the following equation:

$$\frac{Cl_2 \text{ feed, } \frac{lb}{hr}}{(\% \text{ available } Cl_2)} * 8.34 \frac{lb}{gal} = Na - \text{hypo}_{\text{feed}}, \frac{gal}{hr} \quad (\text{Eq. 11})$$

where,

$Cl_2 \text{ feed}$ = chlorine feed rate into main, lbs of Cl_2 as 100% available chlorine /hr

$Na\text{-hypo}_{\text{feed}}$ = rate of sodium hypochlorite solution injection, gal/hr

If a sodium hypochlorite solution must be diluted with water to prepare for injection into a main a given volume of a solution having a lower chlorine concentration (e.g., diluting a 15 percent available chlorine solution to form a 5 percent available chlorine solution), then the following equation may be used to determine the volume of concentrated sodium hypochlorite required:

$$\frac{(\text{gal dilute soln}) * (\% \text{ available } Cl_2 \text{ dilute soln})}{(\% \text{ available } Cl_2 \text{ concentrated soln})} = \text{gal concentrated soln} \quad (\text{Eq. 12})$$

C. Slug Method

The slug method consists of the formation of a slug of chlorinated water in the main with a free chlorine concentration of at least 100 mg/L. The slug of highly chlorinated water must flow through the main at a slow enough rate so that all parts of the main and its

appurtenances will be exposed to the highly chlorinated water for a period of at least 3 hours. As the slug moves through the main, all valves must be fully operated to ensure complete disinfection. This method would be appropriate for long, large diameter mains where the continuous feed method would be impractical. It could also be used for smaller mains of limited length where the continuous method's requirement of 24 hours of contact time cannot be satisfied. By application of a solution having a higher initial chlorine dose, 100 mg/L, the required minimum contact time may be reduced from 24 hours to 3 hours.

The slug of chlorinated water is typically formed through the application of gaseous chlorine, although hypochlorite solutions, purchased as premixed or mixed on site, could also be employed. For relatively small mains, hypochlorite could be added to potable water in a tanker truck or a large container such that the chlorinated water would have an initial concentration of at least 100 mg/L free chlorine. The chlorinated water from the tanker truck or large container could then be pumped into a section of the main until full as indicated by a discharge from the outlet at the other end of the section of main being repaired.

The free chlorine residual must be regularly measured in the slug during the required minimum 3 hours of contact time. If at any time, the free chlorine residual in the slug drops below 50 mg/L, additional chlorine must be applied to the head of the slug in order to reestablish the level of free chlorine in the slug to be at least 100 mg/L.

Step 4: Final Flushing of Mains

After the appropriate minimum retention period, highly chlorinated water should be flushed from the main until chlorine residual measurements show that the chlorine concentration of the water leaving the repaired section of main is no higher than that generally prevailing in the distribution system. Care must be exercised when disposing of water with excessive chlorine residuals. Chlorine is toxic to fish and other aquatic life. Disposal of chlorinated water into storm sewers without prior neutralization of the chlorine residual should be avoided if residual chlorine will still be present when the water directly or indirectly reaches a stream, river, or lake.

Neutralization of the chlorine residual remaining in the water can be accomplished by application of a de-chlorination chemical to the highly chlorinated water in a temporary retention pond, container, or tanker truck. Typical de-chlorination chemicals employed are sulfur dioxide (SO_2), sodium bisulfite (NaHSO_3), sodium sulfite (Na_2SO_3), and sodium thiosulfate ($\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$). The amounts of these chemicals required to neutralize various residual chlorine concentrations in 100,000 gallons of water are listed in Table 6. While the application of de-chlorination chemicals to highly chlorinated waters quickly reduces the level of free available chlorine, significant reductions can also be achieved by exposure of these waters to sunlight in open ponds or in containers. Note that over-feeding a de-chlorination chemical can deoxygenate the receiving water, so the de-chlorination process must be carefully controlled.

TABLE 6 - AMOUNTS OF CHEMICALS REQUIRED TO NEUTRALIZE VARIOUS RESIDUAL CHLORINE CONCENTRATIONS IN 100,000 GALLONS OF WATER

Residual Chlorine Concentration (mg/L)	Chemical Required			
	Sulfur Dioxide (lb)	Sodium Bisulfite (lb)	Sodium Sulfite (lb)	Sodium Thiosulfate (lb)
1	0.8	1.2	1.4	1.2
10	8.3	12.5	14.6	12.0
25	20.9	31.3	36.5	30.0
50	41.7	62.6	73.0	60.0

Adapted from AWWA Standard C651-05.

Step 5: Bacteriological Testing (Optional)

AWWA Standard C651 requires that after the final flushing two consecutive sets of bacteriological samples within a 24 hour period be collected from the new main. At least one set of samples shall be collected from every 1200 ft. of the new main, one set from the end of the line and at least one set from each branch. The samples are tested for the presence of coliform organisms in accordance with *Standard Methods for the Examination of Water and Wastewater* (APHA *et al.*, 2005). KDHE does not require bacteriological testing of new mains but recommends such tests to confirm the effectiveness of the disinfection procedure. It is not uncommon for a public water supply system to require bacteriological testing of mains as part of their standard specifications for the installation of water mains. Unless the provisions of AWWA Standard C651 are incorporated by reference in the system's specifications, the specifications for bacteriological testing should provide: the type, number, and frequency of samples for bacteriological tests; the method of initial sample collection to include repeat sample collection; the party or parties responsible for testing; and the laboratory selection requirements.

Attachment B to this appendix provides a brief summary of bacteriological sampling procedures and analytical methods; however, the most current procedures and methods as outlined in the drinking water regulations should always be employed.

EMERGENCY WATER MAIN DISINFECTION PROCEDURES

When repairs require that mains be opened and depressurized under emergency conditions such as a break or other physical failure of the pipeline, the necessity of restoring water service as soon as possible prevents complete compliance with the routine main disinfection procedures of AWWA Standard C651. Alternate disinfection procedures under such conditions are described in more

Appendix D: Procedures for the Disinfection of Water Mains

detail in an article published by Scoot R. Yoo in OPFLOW (Yoo, 1986). The following recommended disinfection procedure is based in part on the article.

The entry of contaminants into the repaired main should be minimized. When feasible, employ clamps, sleeves or other devices to avoid having to take the main out of service and to depressurize it to make the necessary repairs. If the main must be taken out of service and depressurized while repairs are being made it is important that excavated areas be dewatered to the extent practical to prevent dirty water from contacting or entering the pipe. When a pipe is cut and a section removed, the inside of the remaining pipe ends must be examined and pieces of pipe, scale, or other debris removed. Temporary plugs for all open ends of pipes must be provided.

If the main must be depressurized and opened, then the pipe should be disinfected by swabbing it with a concentrated chlorine solution and then thoroughly flushed upon completion of repairs. Alternatively, a high chlorine residual should be maintained in the repaired section of the main for an appropriate period of time. The swabbing method is quick and is generally effective under repair conditions that do not pose a threat of significant contamination. The swabbing method, however, should not be utilized where there is a potential for significant contamination of the main, e.g., when sewage is detected in the trench during repairs.

Swabbing Method

All new pieces of pipe, couplings, clamps, sleeves, and other materials used in the repair must be thoroughly swabbed with a concentrated (1 percent available chlorine or greater) chlorine solution to disinfect all surfaces which will come in contact with potable water. The concentrated chlorine solution may be prepared by adding 2 oz of calcium hypochlorite (65 percent available chlorine) or 26 fl oz of household bleach (5 percent available chlorine) to 1 gallon of water. Clean rags or a sprayer are typically employed to apply the concentrated chlorine solution. Longer pieces of pipe may be disinfected using a clean mop. Proper personal protection such as rubber gloves and goggles should be worn. Respiratory protection equipment should also be worn when ventilation is inadequate.

Hypochlorite Injection or Addition of Pre-mixed Solution

In both of these methods of disinfection, the repaired section of main is briefly contacted with chlorinated water that will have high chlorine residual.

Preliminary Steps

Both methods require the repaired section of main to be isolated from the distribution system. This will require that all service connections along the section of main to be disinfected be shut off. Temporary connections for filling the main with water as well as a method of flushing the main through a hydrant or other temporary outlet must be provided. The isolated section of main must be initially flushed to remove dirty water, debris, and air.

Appendix D: Procedures for the Disinfection of Water Mains

Hypochlorite Injection

In the hypochlorite injection method, liquid sodium hypochlorite is injected into the flowing main by means of a chemical feed pump to establish a high chlorine residual in the repaired section of the main (Figure 1). The initial required chlorine dose is 300 mg/L, verified by measuring the chlorine residual in the water flushed out through an outlet in the other end of the repaired section. The minimum amount of hypochlorite solution required to treat one pipe volume with an initial chlorine dose of 300 mg/L can be calculated using the following equation:

$$\frac{300 \frac{\text{mg}}{\text{L}}}{\text{Conc}_{\text{soln}}} * \text{Vol}_{\text{main}} = \text{Vol}_{\text{soln}} \quad (\text{Eq. 13})$$

where,

$\text{Conc}_{\text{soln}}$ = concentration of chlorine in a sodium hypochlorite solution, in mg/L as Cl_2 , where 1 percent available chlorine solution is approximately equal to 10,000 mg/L.

Vol_{main} = volume of main, gal

Vol_{soln} = volume of sodium hypochlorite as chlorine solution, gal

Table 7 includes the minimum volumes of sodium hypochlorite solution (5 and 12.5 percent available chlorine) necessary to achieve an initial chlorine dosage of 300 mg/L in 100 ft. of main. Volumes in excess of the table values will be necessary because pumping must continue until the minimum chlorine dose is verified at the flushing outlet.

TABLE 7 - HYPOCHLORITE REQUIRED PER 100 FT OF MAIN

Pipe Size (in)	Total Pipe Volume (gal)	Hypochlorite Solution				Hypochlorite Granules	
		gal of 5-percent		gal of 12.5-percent		ounces of 65-percent	
		Dose 100 mg/L	Dose 300 mg/L	Dose 100 mg/L	Dose 300 mg/L	Dose 100 mg/L	Dose 300 mg/L
2	16.3	0.03	0.10	0.013	0.039	0.33	1.0
4	65.3	0.13	0.39	0.052	0.16	1.3	4.0
6	147	0.29	0.88	0.12	0.35	3.0	9.0
8	261	0.52	1.6	0.21	0.63	5.4	16.1
10	408	0.82	2.4	0.33	0.98	8.4	25.1
12	587	1.2	3.5	0.47	1.4	12.1	36.2
16	1044	2.1	6.3	0.84	2.5	21.4	64.3

Note: 5-percent chlorine solution = 50,000 ppm or mg/L free chlorine.

Appendix D: Procedures for the Disinfection of Water Mains

Addition of Premixed Solution

An alternate method is the preparation of a premixed chlorine solution in sufficient volume to completely fill the repaired section of main. A hypochlorite compound is added to potable water in a tanker truck or other large container in the proportions indicated in Table 7 to form a thoroughly mixed solution having a chlorine concentration of at least 300 mg/L. The chlorine solution from the tanker truck or large container is then pumped into the repaired section of the water main until the water main is full as indicated by a discharge through a hydrant or other outlet device at the other end of the section of water main being tested.

Minimum Contact Period

The minimum contact period for an initial chlorine dose of 300 mg/L is 15 minutes. After the minimum 15 minute contact period, a chlorine residual of at least 100 mg/L should be verified. Lower initial chlorine doses may be used for longer contact periods (e.g., 100 mg/L initial chlorine dose with a 3 hour contact time).

Final Steps

The heavily chlorinated water is flushed from the main until the chlorine residual is reduced to the level normally present in water supplied to the area. Consideration should be given to the collection of bacteriological samples after the disinfection procedure has been completed to provide a record of the effectiveness of the disinfection procedures where repairs were made under conditions that posed a threat of contamination.

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ATTACHMENT A

METHODS FOR MEASURING FREE CHLORINE RESIDUAL

Standard Methods for the Examination of Water and Wastewater (APHA *et al.*, 2005) describes eight methods for measuring residual chlorine concentration. Of the eight, the amperometric titration, DPD colorimetric, DPD ferrous titrimetric, and iodometric titration methods are the most commonly practiced. The amperometric titration method is the most common method of measurement practiced in the laboratory and the DPD colorimetric method is the most common and simplest method of measurement practiced in the field.

DPD colorimetric methods used in the field typically involve collecting a water sample in the sample tube of a DPD test kit; adding the DPD color reagent (N,N-diethyl-p-phenylenediamine) provided in the kit to the water sample; and then matching the resulting color of the sample with a color on the comparator wheel to estimate the free chlorine residual in mg/L. The magenta or red coloring of the sample can be observed as the DPD is oxidized by the free chlorine in the sample. The intensity of the color is directly proportional to the free chlorine concentration in the sample. DPD colorimetric field test kits for a variety of ranges of free chlorine are widely available.

Each DPD colorimetric chlorine test kit is designed to measure a specified range of free chlorine concentration. Low range test kits typically measure free chlorine concentrations as high as 3.5 to 5 mg/L. Some manufacturers have produced high range test kits that are capable of measuring free chlorine concentrations at the level of doses required for disinfection of water mains, e.g. 25 mg/L. A low range test kit can, however, be used to measure a free chlorine concentration higher than the kit's range by diluting the sample to reduce the free concentration to be within range of the test kit. Samples can be diluted using the graduated cylinder dilution method or the DPD drop dilution method.

It is important to note that if the concentration of chlorine in the sample exceeds the highest concentration for which a DPD test kit is valid, or if the reagents are not added in the proper order, the results are likely to be erroneous.

Graduated Cylinder Dilution Method

Collect a 2 mL sample of highly chlorinated water and pour the sample into an empty 50 mL or larger graduated cylinder. Add distilled water for a total of 50 mL and gently mix. Distilled water can be purchased in most grocery and convenience stores in gallon containers.

Transfer from the graduated cylinder the volume of diluted chlorinated water specified by the test kit to the test kit's sample tube. Add DPD reagent, mix, and then estimate the free chlorine concentration based on a comparison of the color of the diluted sample with the kit's standards according to the kit's instructions.

Appendix D: Procedures for the Disinfection of Water Mains (Attachment A)

Multiply the estimated free chlorine concentration by the dilution factor, which is calculated as follows:

$$\frac{(\text{Volume of distilled water} + \text{Volume of chlorinated sample})}{(\text{Volume of chlorinated sample})} = \text{Dilution Factor} \quad (\text{Eq. A1})$$

When 2 mL of sample are combined with 48 mL of distilled water in a graduated cylinder, the dilution factor is 25 as determined below:

$$\frac{(48 \text{ mL of distilled water} + 2 \text{ mL of sample})}{(2 \text{ mL of chlorinated sample})} = \text{Dil. Factor of 25}$$

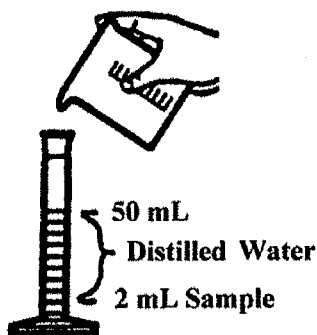


Figure A-1 Dilution of Sample in Graduated Cylinder.

For example, if it is determined that the diluted sample from the graduated cylinder has a chlorine residual of 1 mg/L, the undiluted sample from the disinfected main would have a residual of 25×1 mg/L or 25 mg/L. If it is not possible to accurately determine the chlorine residual of the undiluted sample, it may be necessary to apply a different dilution to the sample. For example, if the anticipated level of chlorine residual is around 100 mg/L, as it might be in for the slug method, a more appropriate dilution factor would be 50. This level of dilution could be obtained by diluting 1 mL of sample with 49 mL of distilled water.

DPD Drop Dilution Method

Add 10 mL of distilled water and one premeasured packet or powder pillow of DPD reagent (or 0.5 mL of DPD solution) to the DPD test kit's sample tube.

Using an eye dropper, add a sample of the highly chlorinated water on a drop-by-drop basis to the kit's sample tube until a color is produced.

Appendix D: Procedures for the Disinfection of Water Mains (Attachment A)

Record the number of drops added to the sample tube. Assume one drop equals 0.05 mL.

Determine the free chlorine concentration in the kit's sample tube that contains the drops of sample, 10 mL of distilled water, and the DPD reagent by means of a colorimetric comparison with the standard according to the test kit's instructions.

Estimate the chlorine residual in the chlorinated sample from the disinfected main with the following equation:

$$\frac{(\text{Cl}_2 \text{ Residual}_{\text{sample-tube}}, \frac{\text{mg}}{\text{L}}) * (\text{Vol}_{\text{distilled-water}}, \text{mL})}{(\text{Vol}_{\text{sample, drops}} * (0.05 \frac{\text{mL}}{\text{drop}}))} = \text{Cl}_{2 \text{ residual-sample}}, \frac{\text{mg}}{\text{L}} \quad (\text{Eq. A2})$$

For example, assume three drops of chlorinated water from the disinfected main determined a free chlorine concentration of 0.6 mg/L in 10 mL of distilled water in the kit's sample tube. Determine the free chlorine concentration in the sample of chlorinated water from the disinfected main with Eq. A2:

$$\frac{(0.6 \text{ mg / L}) * (10 \text{ mL})}{(3 \text{ drops}) * (0.05 \text{ mL / drop})} = 40 \text{ mg / L}$$

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ATTACHMENT B

BACTERIOLOGICAL SAMPLING AND ANALYSIS

AWWA C651-05 requires that two consecutive sets of samples, taken at least 24 hours apart, be collected from the main and examined for bacteriological contamination after the final flushing and prior to connecting the new main to the distribution system. If the results of the examination of the initial bacteriological samples are unsatisfactory, the new main should be flushed and additional samples collected and examined. According to AWWA C651-05, if the results of the examination of any of the additional samples are also unsatisfactory, the main must be re-chlorinated, flushed, and resampled until satisfactory results are obtained. KDHE recommends bacteriological testing of newly installed or repaired mains.

Analytical Methods

AWWA Standard C651-05 requires that the samples be examined for bacteriological quality in accordance with AWWA's *Standard Methods for the Examination of Water and Wastewater* (APHA *et al.*, 2005). Coliforms are the indicator organisms used in monitoring the bacteriological quality of drinking water. The maximum contaminant level for total coliforms under the Safe Drinking Water Act is based on the presence or absence of the indicator bacteria, not on density or direct count. Four commonly utilized laboratory methods of examination for coliforms are described in *Standard Methods for the Examination of Water and Wastewater*: MMO-MUG, multiple tube fermentation (MTF), presence-absence (PA), and membrane filtration (MF).

Several private laboratories located within the state of Kansas are certified for microbiological examination of drinking water samples. A current list can be obtained from the Public Water Supply Section of KDHE at (785) 296-5514, KDHE's Laboratory Improvement Program Office at (785) 296-3811 or <http://www.kdheks.gov/lipo/index.html>, or the KDHE district offices. The laboratory that is chosen to perform the analysis will typically provide the sampler with instructions and appropriate containers for sample collection. The KDHE microbiology laboratory is also available for examination of bacteriological samples. Scheduling for sample bottles and their examination by the KDHE microbiology laboratory may be requested from the Public Water Supply Section of KDHE at (785) 296-5514. Public Water Supply Systems that currently receive monthly sample bottles for monitoring distribution system samples for compliance with the Total Coliform Rule must not utilize their regular monthly bottle allotment for assessing the effectiveness of disinfection procedures on mains. Additional sample bottles requested for this sampling effort must be requested as a special project.

Number of Samples

AWWA Standard C651-05 provides that at least one set of samples for bacteriological examination be collected from every 1,200 ft of the new water main, plus one set from the end of the

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line, and at least one set from each branch. If trench water or excessive quantities of dirt entered the new main during construction, samples should be taken at intervals of approximately 200 ft and identified by location.

Sample Collection Procedures

Use only sterile bottles furnished by the laboratory. Keep the bottles sealed until used. Each sample bottle should contain a de-chlorinating agent (typically, sodium thiosulfate) in sufficient amount to neutralize any residual chlorine in the water sample. Do not rinse the bottle prior to taking the sample as such rinsing will remove the de-chlorinating agent and render the subsequent sample invalid. Samples are not to be taken from a sampling fixture that has an aerator attached or from a sampling fixture attached to pipe or pipe/hydrant combination having a weep hole.

C651-05 prohibits collection of samples from hoses or fire hydrants. Experience has shown that the examination of samples collected from these types of sampling locations may result in a false presence of coliforms due to contamination of the sample. AWWA Standard C651-05 recommends the use of a specially installed sampling tap consisting of a smooth, unthreaded, 0.5-inch hose bib. Alternatively, a corporation stop installed in the main equipped with a copper-tube gooseneck assembly may be utilized as a sampling tap. After the samples have been collected, the gooseneck assembly may be removed and retained for future use.

Be sure that the heavily chlorinated water has been thoroughly flushed from the main before sampling. Run water through the sampling tap at a steady rate 3 to 5 minutes before beginning sampling procedure.

Wash hands thoroughly. Remove the bottle lid just before filling, holding the lid in your free hand. Do not contaminate the inner surface of the cap of the bottle with your hands. Fill the bottle to the shoulder or fill line. Do not overflow the bottle or splash water into or out of the bottle or onto the outside rim of the bottle. Replace the lid and tighten securely.

Complete the appropriate sample documentation provided by the laboratory. This will typically include a sample label and chain of custody form. If the KDHE laboratory is being utilized, a KDHE Sampling Data Card must be completed instead of a chain of custody form. The KDHE Sampling Data Card requires completion of the following information: collection date, collector's last name and first initial, time of collection, collection location, and chlorine residual.

Sample Delivery to Laboratory

Deliver the samples to the laboratory promptly after collection. There are strict time limits on the amount of time that may elapse between sample collection and analysis before the sample is considered too old to analyze. Check with your laboratory on sample holding time requirements. The EPA requires that samples reach the laboratory within 30 hours of collection. Unless special arrangements are made, schedule the collection of samples so that they do not arrive at the laboratory on weekends or holidays. Samples should be held at a temperature of 40 °F (4°C). If practicable, place samples in an iced cooler for storage during transport if transport time will exceed

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one hour. At no time, however, should the sample container be allowed to become immersed or submerged in the ice or melted ice water. Check with the laboratory for specific packaging and transport recommendations.

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ATTACHMENT C

EXAMPLE CALCULATIONS FOR THE DISINFECTION OF WATER MAINS WITH CHLORINE

1. **FLUSHING RATE** – Calculate the flushing rate for a given velocity (Table 1).

Example:

Calculate the flushing rate for a 6-inch diameter pipe which would provide a velocity of 2.5 ft/sec within the main.

Formulas:

$$\text{Area}_{\text{main}}, \text{ft}^2 = \pi[(\text{dia}, \text{ft})^2/4] = \text{cross-sectional area of main}$$

$$\begin{aligned} \text{Flushing rate, gpm} \\ = (\text{Area}_{\text{main}}, \text{ft}^2) * (\text{Velocity, ft/sec}) * (7.48 \text{ gal/ft}^3) * (60 \text{ sec/min}) \end{aligned}$$

Solution:

$$\text{Area}_{\text{main}}, \text{ft}^2 = \pi[(6 \text{ in}) * (1 \text{ ft}/12 \text{ in})]^2/4 = 0.196 \text{ ft}^2$$

$$\begin{aligned} \text{Flushing rate, gpm} \\ = (0.196 \text{ ft}^2) * (2.5 \text{ ft/sec}) * (7.48 \text{ gal/ft}^3) * (60 \text{ sec/min}) \\ = 220 \text{ gpm} \end{aligned}$$

2. **PREPLACEMENT OF HTH GRANULES IN MAIN** – Calculation of the amount of calcium hypochlorite (HTH) granules required for disinfection of a water main with a chlorine dose of 25 mg/L (Table 3).

Example:

Calculate the quantity of calcium hypochlorite granules required to disinfect 1,000 feet of a 4-inch diameter PVC pipe. Assume granules contain 65 percent available chlorine by weight.

Formulas:

$$\text{Vol}_{\text{main}}, \text{MG} = \pi(\text{dia}, \text{ft})^2/4 * (\text{length}, \text{ft}) * (7.48 \text{ gal/ft}^3) * (1 \text{ MG}/1 \times 10^6 \text{ gal})$$

$$\text{Cl}_2 \text{ needed, lb} = (\text{Vol, MG}) * (\text{Cl}_2 \text{ dose, mg/L}) * (8.34 \text{ lb/gal})$$

Calcium hypochlorite needed, lb = (Cl₂ needed, lb)/(percent available Cl₂/100)

Solution:

$$\begin{aligned}\text{Vol}_{\text{main}}, \text{MG} &= \pi[(4 \text{ in})^2/4] * (1 \text{ ft}/12 \text{ in})^2 * (1,000 \text{ ft}) * (7.48 \text{ gal}/\text{ft}^3) * (1 \text{ MG}/1 \times 10^6 \text{ gal}) \\ &= 0.000653 \text{ MG}\end{aligned}$$

$$\begin{aligned}\text{Calcium hypochlorite needed for disinfection of 1,000 ft of 4-in pipe, oz} \\ &= (0.000653 \text{ MG}) * (25 \text{ mg/L Cl}_2) * (8.34 \text{ lb/gal}) * (16 \text{ oz/lb}) / (0.65) \\ &= 3.4 \text{ oz}\end{aligned}$$

This answer could also be obtained from Table 3 which is expressed in terms of the ounces of calcium hypochlorite granules required each 500-foot interval. In this example, since the pipe is 1,000 feet long, the amount of granules required must be doubled so the amount needed is 2 * 1.7 oz = 3.4 oz.

3. **PREPLACEMENT OF HTH TABLETS IN MAIN – Calculation of the number of 5-g calcium hypochlorite tablets (65 percent available chlorine) for disinfection of a water main with an initial chlorine dose of 25 mg/L (Table 4).**

Example:

Calculate the number of 5-g calcium hypochlorite tablets (65 percent available chlorine) necessary to apply an initial chlorine dose of 25 mg/L to 846 feet of 8-inch diameter PVC pipe.

Formulas:

$$\text{Vol}_{\text{main}}, \text{MG} = \pi[(\text{dia, ft})^2/4] * (\text{length, ft}) * (7.48 \text{ gal}/\text{ft}^3) * (1 \text{ MG}/1 \times 10^6 \text{ gal})$$

$$\begin{aligned}\text{Calcium hypochlorite needed, lb} \\ &= (\text{Vol, MG}) * (\text{Cl}_2 \text{ dose, mg/L}) * (8.34 \text{ lb/gal}) / (\text{percent available Cl}_2/100)\end{aligned}$$

Solution:

$$\begin{aligned}\text{Vol}_{\text{main}}, \text{MG} &= \pi[(8 \text{ in})^2/4] * (1 \text{ ft}/12 \text{ in})^2 * (846 \text{ ft}) * (7.48 \text{ gal}/\text{ft}^3) * (1 \text{ MG}/1 \times 10^6 \text{ gal}) \\ &= 0.00221 \text{ MG}\end{aligned}$$

$$\begin{aligned}\text{Calcium hypochlorite needed for disinfection of 846 ft of 8-in pipe, lb} \\ &= (0.00221 \text{ MG}) * (25 \text{ mg/L Cl}_2) * (8.34 \text{ lb/gal}) / (65\%/100) \\ &= 0.71 \text{ lb}\end{aligned}$$

$$\begin{aligned}\text{Weight per 5-g tablet of calcium hypochlorite, lb/tablet} \\ &= (5 \text{ g/tablet}) * (0.035274 \text{ oz/g}) * (1 \text{ lb}/16 \text{ oz}) \\ &= 0.011 \text{ lb/tablet}\end{aligned}$$

$$\begin{aligned} &\text{Number of tablets providing 0.71 lb of calcium hypochlorite, tablets} \\ &= (0.71 \text{ lb calcium hypochlorite}) * (1 \text{ tablet}/0.011 \text{ lb}) \\ &= 64.5 \text{ tablets} \end{aligned}$$

Since there are approximately 47 sections of 18-foot sections in an 846-foot length of main, the number of tablets required per 18-foot section is $64.5 \text{ tablets}/47 \text{ sections} = 1.37 \text{ tablets}$ per section. Assuming partial tablets are not possible, 2 tablets should be used per section of pipe for a total of 94 tablets for the 846 ft length of pipe. As Table 4 indicates, this solution could also be obtained from 2 tablets for each 18-foot section of 8-inch pipe.

4. CONTINUOUS METHOD

Procedure 1: Addition of Premixed Chlorinated Water (Table 5)

Example:

Calculate the amount of hypochlorite (sodium or calcium) necessary for disinfection of 500 ft of 6-inch main by the addition of premixed chlorinated water. For this problem, assume calcium hypochlorite is 65 percent available chlorine and sodium hypochlorite is a 15 percent available chlorine solution.

Formulas:

$$\text{Vol}_{\text{main}}, \text{ MG} = \pi[(\text{dia}, \text{ ft})^2/4] * (\text{Length}, \text{ ft}) * (7.48 \text{ gal}/\text{ft}^3) * (1 \text{ MG}/1 \times 10^6 \text{ gal})$$

$$\begin{aligned} &\text{Utilizing calcium hypochlorite,} \\ &\text{lbs of HTH} = (\text{Vol}_{\text{main}}, \text{ MG}) * (8.34 \text{ lb}/\text{gal}) * (25 \text{ mg}/\text{L Cl}_2) / (\text{percent available Cl}_2/100) \end{aligned}$$

$$\begin{aligned} &\text{Utilizing sodium hypochlorite,} \\ &\text{minimum volume, gal} = (\text{Vol}_{\text{main}}) * (25 \text{ mg}/\text{L Cl}_2) / (\text{Conc}_{\text{soln}}, \text{ mg}/\text{L as Cl}_2), \text{ where a 1} \\ &\text{percent available chlorine solution as sodium hypochlorite} \\ &\text{is approximately equivalent to 10,000 mg}/\text{L as Cl}_2. \end{aligned}$$

Solution:

$$\begin{aligned} \text{Vol}_{\text{main}}, \text{ MG} &= \pi[(6/12)^2/4] * (500 \text{ ft}) * (7.48 \text{ gal}/\text{ft}^3) * (1 \text{ MG}/1 \times 10^6 \text{ gal}) \\ &= 7.34 \times 10^{-4} \text{ MG or } 734 \text{ gal} \end{aligned}$$

Utilizing 65 percent available chlorine calcium hypochlorite, the required amount of HTH in lbs to be added to 734 gal:

$$\begin{aligned} &= (7.34 \times 10^{-4} \text{ MG}) * (8.34 \text{ lb}/\text{gal}) * (25 \text{ mg}/\text{L Cl}_2) / (0.65) \\ &= 0.24 \text{ lb or } 3.8 \text{ oz} \end{aligned}$$

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The volume of 15 percent available chlorine sodium hypochlorite to be added to 734 gallons:

$$\begin{aligned} &= (734 \text{ gal}) * (25 \text{ mg/L Cl}_2) / (150,000 \text{ mg/L}) \\ &= 0.12 \text{ gal} \end{aligned}$$

This answer can also be obtained from Table 5 which indicates that for a 100-foot section of 6-inch diameter water main, 0.024 gal of 15 percent available chlorine sodium hypochlorite or 0.75 ounces of 65 percent available chlorine HTH are required for a 25 mg/L chlorine dose. Since the problem statement specifies a 500-foot main, the table entries should be multiplied by 5 yielding the minimum quantities of 0.12 gal of 15 percent available chlorine sodium hypochlorite or 3.8 oz of 65 percent available chlorine HTH.

Procedure 2: Injection of Concentrated Chlorine Solution (Table 5)

Example:

Calculate the amount of hypochlorite (sodium or calcium) necessary for disinfection of 5,250 ft of 8-inch diameter main by the continuous method. For this problem, assume calcium hypochlorite is 65 percent available chlorine and sodium hypochlorite is a 15 percent available chlorine solution.

Formulas:

$$\text{Vol}_{\text{main}}, \text{MG} = \pi[(\text{dia}, \text{ft})^2/4] * (\text{length}, \text{ft}) * (7.48 \text{ gal/ft}^3) * (1 \text{ MG}/1 \times 10^6 \text{ gal})$$

$$\begin{aligned} \text{Chlorine feed rate (Cl}_2 \text{ feed), lb/hr} \\ &= (Q_{\text{fill}}, \text{gpm}) * (1440 \text{ min/day}) * (1 \text{ day}/24 \text{ hr}) * (1 \text{ MG}/1 \times 10^6 \text{ gal}) * (25 \text{ mg/L}) \end{aligned}$$

Calcium Hypochlorite

$$\text{Calcium hypochlorite, lb/hr} = (\text{Cl}_2 \text{ feed, lb/hr}) / (\text{percent available Cl}_2/100)$$

$$\text{HTH, in lb} = (\text{Vol}_{\text{main}}, \text{MG}) * (8.34 \text{ lb/gal}) * (25 \text{ mg/L Cl}_2) / (\text{percent available Cl}_2/100)$$

$$\begin{aligned} \text{Chlorine concentration in prepared chlorine solution, mg/L} \\ &= (\text{HTH, lb}) / (\text{Vol}_{\text{soln}}) * (1 \times 10^6 \text{ gal}/1 \text{ MG}) \\ &\quad * (1 \text{ mg/L}/8.34 \text{ lb/MG}) * (\text{percent available Cl}_2/100) \end{aligned}$$

Sodium Hypochlorite

$$\begin{aligned} \text{Flow rate of water into main (Q}_{\text{fill}}\text{), gpm} \\ &= [(\text{Conc}_{\text{soln}}) * (Q_{\text{soln}}, \text{gpm}) / 25 \text{ mg/L}] - (Q_{\text{soln}}, \text{gpm}) \end{aligned}$$

Solution:

$$\begin{aligned}\text{Vol}_{\text{main, MG}} &= \pi[(8 \text{ in})^2(1 \text{ ft}/12 \text{ in})]/4 \times (5,250 \text{ ft}) \times (7.48 \text{ gal}/\text{ft}^3) \times (1 \text{ MG}/1 \times 10^6 \text{ gal}) \\ &= 0.0137 \text{ MG}\end{aligned}$$

Calcium Hypochlorite

Assume a chlorine solution injection rate of 2.5 gal/hr (0.0417 gpm) and a filling rate of 150 gpm.

$$\begin{aligned}\text{Cl}_2 \text{ feed rate, lb/hr} \\ &= (150 \text{ gpm}) \times (1440 \text{ min}/24 \text{ hr}) \times (1 \text{ MG}/1 \times 10^6 \text{ gal}) \times (8.34 \text{ lb}/\text{gal}) \times (25 \text{ mg}/\text{L}) \\ &= 1.88 \text{ lb/hr}\end{aligned}$$

$$\begin{aligned}\text{Calcium hypochlorite feed rate, lb/hr} \\ &= (1.88 \text{ lb/hr}) / (65\%/100) \\ &= 2.89 \text{ lb/hr}\end{aligned}$$

$$\begin{aligned}\text{Calcium hypochlorite necessary for disinfection of 5,250 ft of main, lb} \\ &= (0.0137 \text{ MG}) \times (25 \text{ mg}/\text{L Cl}_2) \times (8.34 \text{ lb}/\text{gal}) / (65\%/100) \\ &= 4.4 \text{ lb}\end{aligned}$$

The time it takes to fill the main, T_{fill} , which may be assumed equivalent to the period of chlorine solution injection, $T_{\text{injection}}$, is determined by dividing the volume of the main by the rate of filling: $13,700 \text{ gal}/150 \text{ gpm} = 91 \text{ min}$. For a chlorine solution injection rate, Q_{soln} , of 0.0417 gpm, the required volume of chlorine solution, Vol_{soln} , is 3.8 gal. The combination of 4.4 lb of HTH in 3.8 gal of water results in a chlorine solution with a concentration estimated by the following:

$$\begin{aligned}\text{Chlorine concentration in solution, mg/L as Cl}_2 \\ &= (4.4 \text{ lb}/3.8 \text{ gal}) \times (65\%/100) \times (1 \times 10^6 \text{ gal}/1 \text{ MG}) \times (1 \text{ mg}/\text{L}/8.34 \text{ lb}/\text{MG}) \\ &= 90,200 \text{ mg}/\text{L} \text{ or an approximately 9\% solution.}\end{aligned}$$

Sodium Hypochlorite

In this case, assume the 15 percent available chlorine sodium hypochlorite solution will be pumped into the main without dilution at an injection rate of 2.5 gal/hr (0.0417 gpm). The required main filling rate, Q_{fill} , can be calculated as follows:

$$\begin{aligned}Q_{\text{fill, gpm}} &= [(0.0417 \text{ gpm}) \times (150,000 \text{ mg}/\text{L})] / (25 \text{ mg}/\text{L}) - 0.0417 = 250 \text{ gpm} \\ \text{The required volume of sodium hypochlorite solution is calculated from } T_{\text{injection}} \text{ and the} \\ &\text{assumed injection rate:}\end{aligned}$$

$$T_{\text{fill, min}} = T_{\text{injection, min}} = 13,700 \text{ gal}/250 \text{ gpm} = 55 \text{ min}$$

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$$\text{Vol}_{\text{soln, gal}} = (55 \text{ min}) * (0.0417 \text{ gpm}) = 2.3 \text{ gal}$$

An alternative approach is to calculate the required feed rate of sodium hypochlorite. For an assumed main filling rate of 150 gpm (Q_{fill}), a 15 percent available chlorine solution, and an injection rate of 2.5 gal/hr (0.0417 gpm), the sodium hypochlorite feed rate ($\text{Na-hypo}_{\text{feed}}$) to form a 25 mg/L chlorine dose is calculated from the following equation:

$$\begin{aligned} \text{Sodium hypochlorite feed rate (15 percent available chlorine), lb/hr} \\ &= [(150 \text{ gpm}) * (1440 \text{ min/day}) * (1 \text{ day/24 hr}) * (1 \text{ MG}/1 \times 10^6 \text{ gal}) \\ &\quad * (8.34 \text{ lb/gal}) * (25 \text{ mg/L Cl}_2)] / (15\%/100) \\ &= 12.5 \text{ lb/hr} \end{aligned}$$

$$\begin{aligned} \text{Sodium hypochlorite feed rate (15 percent available chlorine), gal/hr} \\ &= [(150 \text{ gpm}) * (1440 \text{ min/day}) * (1 \text{ day/24 hr}) * (1 \text{ MG}/1 \times 10^6 \text{ gal}) \\ &\quad * (25 \text{ mg/L Cl}_2)] / (15\%/100) \\ &= 1.5 \text{ gal/hr} \end{aligned}$$

$$T_{\text{fill, min}} = T_{\text{injection, min}} = 13,700 \text{ gal}/150 \text{ gpm} = 91 \text{ min}$$

$$\text{Vol}_{\text{Na-hypo, gal}} = (91 \text{ min}) * (0.0417 \text{ gpm}) = 3.8 \text{ gal of sodium hypochlorite}$$

$$\begin{aligned} \text{Sodium hypochlorite, lb} \\ &= (12.5 \text{ lb/hr}) * (91 \text{ min}) * (1 \text{ hr}/60 \text{ min}) \\ &= 18.9 \text{ lb} \end{aligned}$$

$$\begin{aligned} \text{Sodium hypochlorite, gal} \\ &= (1.5 \text{ gal/hr}) * (91 \text{ min}) * (1 \text{ hr}/60 \text{ min}) \\ &= 2.3 \text{ gal} \end{aligned}$$

5. **SLUG METHOD – Calculation of the amount of chlorine necessary to form a slug of chlorinated water in a main with an initial chlorine dose of 100 mg/L.**

Example:

Calculate the amount of chlorine gas required to create a slug of chlorinated water in 5,000 ft of a 6-inch diameter ductile iron main with an initial chlorine dose of 100 mg/L.

Formulas:

$$\begin{aligned} \text{Vol, MG} \\ &= \pi[(\text{dia, ft})^2/4] * (\text{length of "slug", ft}) * (7.48 \text{ gal/ft}^3) * (1 \text{ MG}/1 \times 10^6 \text{ gal}) \end{aligned}$$

$$\begin{aligned} \text{Chlorine (100 percent available chlorine) needed, lb} \\ &= (\text{Vol, MG}) * (\text{Cl}_2 \text{ dose, mg/L}) * (8.34 \text{ lb/gal}) \end{aligned}$$

Solution:

$$\begin{aligned}\text{Vol}_{\text{main}}, \text{ MG} &= (\pi[(16 \text{ in})^2/4] * (5,000 \text{ ft}) * (7.48 \text{ gal/ft}^3) * (1 \text{ MG}/1 \times 10^6 \text{ gal})) \\ &= 0.0522 \text{ MG}\end{aligned}$$

$$\begin{aligned}\text{Chlorine (100 percent available chlorine) needed, lb} &= (0.0522 \text{ MG}) * (100 \text{ mg/L}) * (8.34 \text{ lb/gal}) \\ &= 43.5 \text{ lb}\end{aligned}$$

6. **EMERGENCY MAIN DISINFECTION – Calculation of the sodium hypochlorite pumping rate and minimum volume of hypochlorite necessary to establish initial chlorine doses of 100 mg/L and 300 mg/L in a water main (Table 7).**

Example:

Calculate the sodium hypochlorite pumping rate (assuming a 5 percent available chlorine solution) and the amount of sodium hypochlorite solution necessary to establish a 300 mg/L chlorine dose in a 300-foot section of a 6-inch diameter main. Assume Q_{fill} into the main is 50 gpm.

Formulas:

$$\begin{aligned}\text{Sodium hypochlorite solution pumping rate, gpm} &= [(\text{Cl}_2 \text{ dose, mg/L}) / (\text{Conc}_{\text{soln}}, \text{ mg/L})] * (Q_{\text{fill}}, \text{ gpm})\end{aligned}$$

$$\begin{aligned}\text{Vol}_{\text{main}}, \text{ gal} &= (\pi(\text{dia, ft})^2/4) * (\text{Length, ft}) * (7.48 \text{ gal/ft}^3)\end{aligned}$$

$$\begin{aligned}\text{Volume of sodium hypochlorite solution, gal} &= [(\text{Cl}_2 \text{ dose, mg/L}) / (\text{Conc}_{\text{soln}}, \text{ mg/L})] * (\text{Vol}_{\text{main}}, \text{ gal})\end{aligned}$$

Solution:

$$\begin{aligned}\text{Sodium hypochlorite solution pumping rate, gpm} &= [(300 \text{ mg/L Cl}_2) / (50,000 \text{ mg/L Cl}_2)] * (50 \text{ gpm}) \\ &= 0.3 \text{ gpm}\end{aligned}$$

$$\begin{aligned}\text{Vol}_{\text{main}}, \text{ gal} &= (\pi[(6 \text{ in})^2/4] * (300 \text{ ft}) * (7.48 \text{ gal/ft}^3)) \\ &= 441 \text{ gal}\end{aligned}$$

$$\begin{aligned}\text{Volume of sodium hypochlorite solution, gal} &= [(300 \text{ mg/L Cl}_2) / (50,000 \text{ mg/L})] * 441 \text{ gal} \\ &= 2.65 \text{ gal}\end{aligned}$$

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$$T_{\text{injection, min}} = 2.65 \text{ gal} / 0.3 \text{ gpm} = 441 \text{ gal} / 50 \text{ gpm} = 8.8 \text{ min}$$

The volume of sodium hypochlorite solution calculated in this problem can also be determined from Table 7. Table 7 indicates for a 6-inch pipe, 0.88 gal of 5-percent sodium hypochlorite solution is required to establish a 300 mg/L dose of Cl_2 in a 100-ft section of main. For a 300-ft section of main, the necessary volume of sodium hypochlorite from Table 7 for a 100-ft section should be multiplied by 3 to give 2.6 gal.